THE CARL MOYER MEMORIAL AIR QUALITY STANDARDS ATTAINMENT PROGRAM (THE CARL MOYER PROGRAM) GUIDELINES –

APPROVED REVISION 2000

November 16, 2000





California Environmental Protection Agency

Air Resources Board

EXECUTIVE SUMMARY

The Carl Moyer Memorial Air Quality Standards Attainment Program (the Carl Moyer Program) is a grant program that funds the incremental cost of cleaner vehicles and equipment. This contributes to the near-term reductions in emissions of oxides of nitrogen (NOx), that are necessary for California to meet its clean air commitments under the State Implementation Plan. These reductions are also necessary for local air districts to meet commitments in their conformity plans, thus preventing the loss of federal highway dollars for local areas throughout California. The program also reduces particulate matter (PM) which is a component of diesel exhaust, that has been identified by the Air Resources Board (ARB or the Board) as a toxic air contaminant. Section 44275 of the Health and Safety Code codifies the Carl Moyer Program with the ARB and the California Energy Commission (CEC) as the administrators.

The ARB, the CEC, and the local air districts have joined together to successfully implement the Carl Moyer Program. Public and private fleets have also demonstrated the desire to incorporate clean air choices if funding is available to defray some of the cost. In the first year, demand for project funding was high (far in excess of available funding), and the resulting emission reductions were extremely cost-effective. The Governor and the Legislature have responded to the program's success in 1998/1999 by making one-time budget appropriations in fiscal years 1999/2000 and 2000/2001 to continue the program. Total program funding for the first three years is $98 million. In the first year of the program, funded projects reduced NOx by about four tons per day (tons/day) and PM from diesel exhaust by about 100 pounds per day (lbs/day). The program is very cost-effective – averaging below $3,000 per ton of NOx reduced based on district estimates for the first year projects. This compares favorably to a typical cost-effectiveness for other air pollution control programs which is $10,000 per ton of NOx reduced. At this same rate, the first three years of the program will provide near term NOx reductions of 14 tons/day. These reductions will continue for a minimum of 5 years, with some projects continuing to provide benefits up to 20 years.

The Board initially approved the Carl Moyer Program Guidelines in February 1999. This document contains revisions that apply to fiscal year 2000/2001 and subsequent funding. The Guidelines provide local air districts with requirements for administering their local programs and criteria for evaluating and selecting reduced-emission heavy-duty engine projects. The Carl Moyer Program is intended to facilitate emission reductions by providing districts with funds to pay for grants for the incremental cost of cleaner heavy-duty vehicles and equipment. The grants are issued locally by air pollution control and air quality management districts that choose to administer a local program. Private companies or public agencies that operate heavy-duty engines in California would continue to apply directly to the local districts for grants.

Health and Safety Code Section 44287(b) requires ARB staff to consider revisions to the program that would improve the ability of the program to achieve its goals. In addition, Section 44297 of the Health and Safety Code established a thirteen-member Carl Moyer Program Advisory Board (Advisory Board) with the responsibility for making recommendations on the need to continue the program, the amount and source of continued funding, and program modifications, if necessary. The Advisory Board recommendations included that the program continue at an increased funding level through 2010 and that the district match fund requirement be capped consistent with the requirements at the $25 million funding level. The Governor and the Legislature responded by signing SB 1300 (Sher) to allow ARB to modify districts' matching fund requirement. The Advisory Board also recommended that a 25% PM reduction target be set for the statewide program, with a 25% local program requirement on air districts designated as non-attainment for the federal PM standard.

The purpose of this guidelines revision is to address recommendations that the Advisory Board made to the Governor and the Legislature pertaining to PM emission reduction requirements and goals and districts' matching fund requirement, as well as to address Health and Safety Code requirements pertaining to incremental fuel costs. These guidelines also contain technical modifications that were considered necessary based on both ARB's and local districts' program experience in the first year; emission inventory adjustments based on new approved on-road and off-road models; and experiences with current and future heavy-duty engine control technologies. The revised Carl Moyer Program Guidelines will continue to make the program a success and ensure that future emission reductions continue to be real, quantifiable, cost-effective, and enforceable.

There are two parts to these revised guidelines. Part I is an overview of the program and the major changes, along with a brief description of ARB's and local air districts' progress with program implementation. Part II is the complete set of revised Carl Moyer Program Guidelines.

PART I

PROGRAM OVERVIEW

PART I

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CARL MOYER PROGRAM OVERVIEW

A. Purpose of the Program

The purpose of the Carl Moyer Program is to reduce emissions and help California meet its air quality obligations under the State Implementation Plan (SIP). Through this program, the districts can provide grants for the extra capital cost of cleaner-than-required vehicles and equipment that have traditionally been powered by heavy-duty diesel engines. The program buys critical near-term emission benefits that California needs to meet impending federal air quality deadlines. Any district can participate in the program by applying directly to ARB. The Carl Moyer Program guidelines were approved in February 1999 and provided guidance and criteria for the first two years of the program.

B. Initial Program

Since its inception in 1998, the Carl Moyer Program has been an overwhelming success. In the first year of the program, ARB distributed $24.5 million in project funds among sixteen local air districts, yet the demand for project funds was more than three times the available amount. Forty percent of those funds were used towards alternative fuel on-road projects, 25 percent towards marine vessel projects, 20 percent towards agricultural irrigation pumps, 10 percent towards forklifts, and the remaining five percent towards other diesel repowers (mostly off-road equipment). Staff estimated that projects funded in the first year of the program would reduce NOx emissions by about 4 tons per day, and PM emissions by about 100 lbs/day.

In June 1999, Governor Davis and the Legislature approved a one-time budget appropriation of $23 million to fund the Carl Moyer Program for fiscal year 1999/2000, the second year of the program. Of these funds, $19 million went to ARB to fund engine projects, and $4 million went to the CEC to fund infrastructure and advanced technology development. ARB has distributed over $18 million of these second year funds to 20 local air districts. About 70 percent of those funds have already been obligated to projects. Districts participating in the second year of the program provided ARB with a program implementation status report in September 2000.

C. Continuing Program

In October 1999, Governor Davis signed AB 1571 formally establishing the framework for the Carl Moyer Program into the Health and Safety Code, Chapter 9. In accordance with that Health and Safety Code, section 44275, et. seq., ARB developed and presented a report to the Governor, Legislature, and the Advisory Board on the progress of program implementation. The Advisory Board, with the assistance of ARB, CEC, and the local air districts, also developed its own report (The Carl Moyer Program Advisory Board Report, March 31, 2000) with recommendations to the Governor and Legislature. The main recommendation of the Advisory Board was to continue the Carl Moyer Program through 2010 at a funding level of $100 million per year. Based on the

Advisory Board Report and other considerations, the Governor and Legislature approved a one-time appropriation of $50 million ($45 million to ARB for engine projects and $5 million to CEC for infrastructure and advanced technology projects) to fund the Carl Moyer Program through a third year (fiscal year 2000/2001).

At an increased funding level, the Advisory Board and ARB recognized it would be a challenge for local districts to meet the matching fund requirement. The Advisory Board recommended to the Governor and the Legislature in its March 2000 report, that for third year funds and beyond the districts' matching fund requirement be capped at a level equivalent to the first year funding level ($25 million). The Governor and the Legislature responded by modifying the Health and Safety Code to allow ARB to modify districts' matching fund requirement, if necessary to benefit the program. The new district matching fund requirement reflects the Advisory Board's recommendations in The Carl Moyer Program Advisory Board Report dated March 31, 2000.

D. Summary of Guideline Revisions

In order to ensure that funding criteria is consistent statewide, even though districts have different implementation schedules, it is necessary to establish an annual revision schedule. Furthermore, the Health and Safety Code, Chapter 9, requires ARB staff to make any proposed revisions of the guidelines available to the public 45 days before final approval.

Revisions to the guidelines were developed as required in Health and Safety Code, Chapter 9, and as recommended by the Advisory Board. The revisions were developed to ensure that emission reductions remain real, quantifiable, and enforceable.

Revisions consider PM emission reductions, the districts' matching fund requirement, funding allocations for the third year, auxiliary power units for reducing idling emissions from heavy-duty vehicles, and provisions to allow the incremental cost of alternative fuels. In addition, existing chapters were revised to include new cost-effectiveness caps, new emission reduction requirements for repowers and retrofit projects, new default emission factors; discount factors for marine vessel emissions; and infrastructure costs for agricultural irrigation pump engines. There were also some minor modifications to correct discrepancies in the guidelines such as omissions and typographical errors. The following sections provide a brief description of the major revisions. The details to the modifications are provided in Part II of this document, which are the complete Carl Moyer Program Guidelines with the modifications incorporated.

1. Districts' Matching Fund Requirement

The total state funding for this program has been $98 million – $25 million for first year, $23 million for the second year, and $50 million for this third year. In the first two years of the program districts provided $1 in match funding for every $2 of Carl Moyer Program funding. The district matching fund requirement is important because it provides a literal "buy-in" from the districts responsible for the selection, monitoring, and enforcement of the project. This requirement helps ensure that the most worthwhile projects are selected. At the increased funding level in the third year, however, ARB and the Advisory Board recognized that districts' ability to provide increased matching funds would be challenging. In fact, the Advisory Board recommended that the districts' matching fund requirement be capped consistent with the requirements at the $25 million funding level. The Governor and the Legislature responded by amending the Health and Safety Code to allow ARB to modify districts' matching fund requirement, if necessary. The new matching fund requirement for districts participating in the third year follows the Advisory Board's recommendation.

2. Funding Allocation for Fiscal Year 2000/20001 Funds

In the third year of the program, staff determined a need to slightly modify the method for determining the district funding allocations. There are several smaller districts that are now designated as non-attainment, thus, increasing the number of non-attainment districts from 9 in the first year to 16. In order to continue providing sufficient funds to the most populated districts and those with very near-term attainment deadlines, funding amounts are based on district's contribution to the total population. Districts with specific allotments are those defined as contributing to at least one percent of the total population. The remainder of the funding is allocated to districts contributing to less than one percent of the total population. Future funds will be divided with 94 percent to districts contributing over one percent of the total population, four percent to districts contributing to less than one percent of the total population, and two percent of the funds provided for ARB's overall program administration and support. Table I illustrates the third year funding allocation.

Table 1 Funding Allocation	
Districts contributing more than 1% of the total population	**Funding Allocation**
Antelope Valley	$ 450,000
Bay Area AQMD	$ 4,306,133
Kern Eastern Desert	$ 450,000
Mojave Desert AQMD	$ 1,535,530
Monterey Bay Unified APCD	$ 450,000
Sacramento Metropolitan AQMD	$ 3,909,604
San Diego County APCD	$ 1,850,344
San Joaquin Valley APCD	$ 7,644,979
Santa Barbara County APCD	$ 450,000
South Coast AQMD	$19,745,849
Ventura County APCD	$ 1,543,561
Subtotal	**$42,336,000**
Districts contributing less than 1% of total population	$ 1,764,000
ARB 2% administration	$ 900,000
TOTAL	**$45,000,000**

3. PM Emission Reduction Requirements and Goals

The Carl Moyer Program was designed to help California achieve NOx emission reductions to meet 1994 SIP requirements. Although the focus of the program was to reduce NOx emissions, the Advisory Board, ARB, and local air districts recognize that PM reductions are needed throughout California because the fine particulate matter of diesel exhaust has been identified as a toxic air contaminant and is a serious public health concern. In its report, the Advisory Board suggested to the Governor and the Legislature that the Carl Moyer Program should encourage further PM reductions. Many of the technologies already funded under the program, such as electric motors and alternative-fueled engines, also reduce PM. However, the Advisory Board concluded that further PM reductions should be encouraged. The Advisory Board's recommendations were that the Carl Moyer Program have a goal to reduce PM emissions from funded projects by 25 percent statewide, except for areas that are designated as non-attainment for the federal PM standard. Those areas designated as serious non-attainment for the federal PM standard are <u>required</u> to reduce PM emissions by 25 percent on a program basis (not a project-by-project basis). Currently, San Joaquin Valley Air Pollution Control District (SJVAPCD) and South Coast Air Quality Management District (SCAQMD) are the only two districts affected by this requirement.

PM emission reductions will be calculated similar to NOx emission reductions. Emission factors are used to calculate PM reductions from the program and are based on the adopted ARB emission inventory models, EMFAC2000 and OFFROAD.

As part of ARB's oversight of the program, ARB staff will determine overall statewide and district compliance with the PM reduction goals and requirements. If the program falls short, ARB staff will propose modifications to the program to achieve the necessary reductions. Specific details pertaining to PM, including PM reduction calculations, are provided in Chapter IX of this document.

4. Incremental Fuel Cost

The Carl Moyer Program has historically paid the incremental capital cost of vehicles and equipment that are cleaner than required. Funding of incremental fuel costs was not allowed under the program. However, cleaner alternative fuels and alternative diesel fuels (e.g. diesel-water emulsions) are available that can reduce NOx and PM emissions. Some non-attainment districts have stated that they need the near-term reductions that those fuels can provide, and would like district funding that is used for incremental fuel costs to count as match funding. ARB staff is currently developing test procedures to evaluate the emission benefits of alternative diesel fuels. ARB will allow, as a district option, funding for incremental fuel cost for alternative fuels and alternative diesel fuels on a case-by-case basis.

AB 2061(Lowenthal) was signed by the Governor, appropriating $500,000 in funding to be used for alternative diesel fuels. It is intended that these funds will be distributed to projects based on the similar criteria to Carl Moyer Program Guidelines.

5. Cost-Effectiveness Requirement

The program's cost-effectiveness limit of $12,000 per ton of NOx reduced was approved in the first year of the program, three years ago. Section 44283 of the Health and Safety Code authorizes the Board to adjust the cost-effectiveness limit to reflect the current inflation and cost of living adjustments. The cost of living in California increases annually according to the Consumer Price Index (CPI). ARB staff has adjusted the cost-effectiveness limits for the years 1998 through 2000 according to the CPI for those years. The new cost-effectiveness limit would be $13,000 per ton of NOx reduced.

6. Dual-Fuel Engines Used in Low Load/High Idle Applications

Dual-fuel engines are available that are certified to reduce NOx to about 60 percent of the required NOx standards. One set of in-use test data shows that while these engines deliver full emission benefits in many applications, the emission benefits are less for engines operated on a low-speed, stop-and-go chassis cycle (the Central Business District cycle). One indication of this is the percentage of alternative fuel consumed by a vehicle during operation. This fuel substitution rate has been high (approximately 80%) during certification, but may be significantly lower in stop-and-go applications.

ARB staff has been working closely with a dual-fuel engine manufacturer to collect additional information and more accurately determine the emission benefits in neighborhood refuse collection. Prior to any dual-fuel project being funded for a stop-and-go application, the manufacturer must provide the Executive Officer with sufficient in-use documentation to demonstrate that the fuel substitution rate is appropriate to yield the certified benefits.

7. Updated Emission Factors

NOx emission factors have been revised to reflect the recently adopted EMFAC2000 emission model (May 2000), which accounts for the settlement agreement between ARB and the diesel engine manufacturers (regarding excess NOx emissions from the use of alternative injection timing strategies) and other adjustments. These new emission factors for heavy-duty on-road vehicles are based on the model year and gross vehicle weight rating (GVWR). These emission factors are listed in Chapter II of the Carl Moyer Program Guidelines.

ARB staff also revised the emission factors for off-road and agricultural irrigation pump engines to reflect portions of the new OFFROAD model approved as of January 2000 that incorporates the most recent regulations for off-road diesel engines adopted by both the U.S. Environmental Protection Agency (USEPA) and ARB. These emission factors are listed in the Guidelines Chapter III and VI, respectively. Where on-road engines are specified in the design for the base or new engine (such as yard hostlers), the on-road emission factors would be used for off-road equipment

8. NOx Emission Reduction Requirement

The Carl Moyer Program Guidelines that were approved in February 1999 set a 25 to 30 percent emission reduction requirement for any retrofit or repower project funded under the program. This requirement, along with the new proposed emission factors, may prevent funding some cost-effective diesel-to-diesel repower projects and retrofit projects. In the first two years of the Carl Moyer Program, projects involving agricultural irrigation pump engine repowers were very popular and funding these types of projects provided California with significant emission reductions. Using the revised emission factors to calculate emission reductions from diesel-to-diesel repowers for 1996 through 1998 model year engines would result in reductions below the 30 percent requirement established in the first and second year of the program.

Section 44282 of the Health and Safety Code authorizes the Board to revise the minimum NOx emission reduction requirement for retrofit and repower equipment, when necessary, in order for the program to achieve its air quality goals. In order to continue funding projects that produce significant emission reductions, the NOx emission reduction requirement for retrofit and repower projects funded in the third year and beyond is 15 percent.

9. Repower Funding Caps

Based on implementation experience during the first two years of the program, ARB staff believes that the funding caps for repower projects may prohibit large off-road and agricultural irrigation pump engine projects from being funded. Emission reductions from the replacement of these engines are significant and can benefit the program in meeting its air quality goals. In order to encourage the participation of large off-road and agricultural irrigation pump engine projects, funding caps for off-road projects have been removed and funding for these projects is to be based on the cost-effectiveness requirement.

10. Emission Calculations to Account for Activity Level Increase/Decrease

In general, the emission reduction benefit of a project can be calculated based on the annual fuel consumed, annual miles traveled, or annual hours operated and should reflect the individual characteristics, such as horsepower, brake specific fuel consumption, and load of both the replacement and current engine. If the annual fuel consumption is used, an energy consumption factor should be calculated (based on the brake specific fuel consumption of each engine) and the activity level should be based on actual annual fuel receipts or other documentation. When the annual mileage or hours of operation is the basis for determining the emission reductions, the activity level would be based on the vehicle odometer or hour meter, respectively. The details for calculating emissions for each project category are presented in Part II of this document.

11. Diesel Hybrids

A promising new heavy-duty engine technology being demonstrated is a hybrid electric engine system. Manufacturers of this technology are currently focusing on the transit bus market, but this technology could also provide emission reductions in other applications. Hybrid buses utilize an electric drive typically with an internal combustion engine (diesel or alternative-fuel) and a traction battery. Recent test data indicate that prototype diesel hybrid transit buses with a particulate filter and low-sulfur diesel fuel can achieve PM emission levels nearly comparable to a current natural gas transit bus. The testing also shows this diesel hybrid technology produces less NOx reduction benefits than natural gas engines. Still, diesel hybrids are an improvement over current diesel engines in terms of emissions and efficiency. With further optimization, hybrid technology (both diesel and alternative-fuel) has the potential to significantly reduce both NOx and PM emissions.

Current California and federal certification test procedures are based on non-hybrid engine duty-cycles and therefore are not able to adequately represent the emissions benefits of the hybrid technology. An effort is currently underway with the Northeast Advanced Vehicle Consortium, ARB, USEPA, and the engine and hybrid manufacturers to improve the certification test. Most of the effort, however, is focused on developing a "quick-fix" certification procedure. This process is not likely to provide a quantitative means of validating the in-use emissions benefits of the hybrid systems. Diesel hybrid vehicle projects will be approved on a case-by-case basis only, at an emission level deemed appropriate by ARB.

12. Auxiliary Power Units for Reducing Idling Emissions From Heavy-Duty Vehicles

It is common practice for truck operators to idle their truck engines for an extended length of time when the vehicles are parked. This keeps the engines and fuel warm, and provides heating and cooling for the truck cabs. This practice increases the amount of fuel used and emissions. An auxiliary power unit (APU) could be installed on a truck to significantly reduce the amount of idling time the truck would normally be subject to. This would result in fuel savings and emission reduction benefits. However, relatively high initial costs of the auxiliary power units have prevented this and similar technologies from being more widely utilized. A new project category has been added to allow Carl Moyer funding for APUs. Carl Moyer Program funds will pay for the installation costs of auxiliary power units, up to $1,500 per unit installed. Chapter X includes project criteria for funding these projects to ensure real emission benefits will be realized in a most cost-effective manner.

13. Discount Factors for Marine Vessels

A discount on emissions from marine vessel engines has been established based on the degree of uncertainty regarding the amount of offshore emissions that actually reach the mainland. The discount is based on the results of the Southern California Ozone Study (the Tracer Dispersion Study) that was conducted by ARB to determine offshore emission impacts. This study was completed in the early summer 2000, and results indicate that the emission reductions from marine vessels would reduce ozone, PM, and toxic emissions that indeed reach the mainland. However, there is still uncertainty on the amount of emissions that actually reach the shore.

Each district establishes an emission inventory boundary that is used for determining the pollutant sources, as well as the amount of emissions within a district. For districts located along the California Coast, that boundary may extend to the coastal water boundary, or at distances closer to the shoreline. Since districts have established inventory boundaries for claiming the amount of emissions within a district, that boundary will also be used to determine the range of offshore emissions that would be included in the emission benefits calculated for marine vessel projects. If a local district has not established an emission inventory boundary, ARB staff has set a default value of 10 miles off shore.

14. Electric Motors for Agricultural Irrigation Pumps

The Carl Moyer Program was designed to provide funding for the increase in capital cost between two engines. Electric motors for agricultural irrigation pumps, however, cost less than diesel engines and therefore do not qualify for incentive funding.

The emission benefits associated with replacing engines with electric motors are significant. ARB evaluated two methods for providing the agricultural communities with incentives to convert to electric motors: funding to cover standby electric chargers or funding to install the power line and peripheral equipment necessary for an electric pump. Current data provided by several utility companies indicate that the operating costs, which include standby (or demand) chargers, vary based on electrical demand at each site, the type of irrigation system, and time of use (e.g., summer vs. winter, peak vs. off-peak), etc. Furthermore, standby chargers may disappear in the near future, since at least one major utility has proposed to eliminate standby chargers and reduce rates for select agricultural customers.

However, the cost of an electric motor plus the cost to set up a power line and connect necessary peripheral equipment to the motor are comparable to the installed cost of a new off-road emission-certified diesel engine. Carl Moyer Program project funds may be used for the incremental cost to install the power line plus peripheral equipment. Districts may fund the cost for extending power lines, provided that those funds come from the district and will count as matching funds. Any funds provided for a project must meet the cost-effectiveness criterion.

15. Expanded Forklift Program

For the first two years of the Carl Moyer Program, funding for electric forklifts was provided via a demonstration project in the SCAQMD. Under this demonstration program, SCAQMD staff was successful at incentivizing electric forklift projects that may not have occurred without funding. In addition, the SCAQMD staff determined that it was appropriate to set a cost-effectiveness criterion of $3,000 per ton of NOx reduced for forklift projects. The forklift demonstration program is now allowed statewide, including forklifts between 3,000 and 6,000 pound lift capacity, under the general program. Forklifts have separate project criteria, including a $3,000 cap on cost-effectivenes.

16. October 2002 Diesel-to-Diesel Repowers

Previously, replacing early 1990s electronically controlled engines with similar engines manufactured in the late 1990s (electronic-to-electronic repowers) was not allowed. Electronically controlled engines manufactured in the late 1990s are equipped with advanced computer controls that have alternative strategies for fuel management. When these engines operate outside of the certification test procedure, the alternative strategies allow the engines to produce excess NOx emissions above the certified standard. This practice is commonly referred to as “off-cycle NOx emissions”. A settlement agreement was reached between the engine manufacturers, ARB, and the USEPA requiring that many of the engine manufacturers introduce new engines with significantly lower NOx emissions beginning in October 2002. Repowering older electronically controlled trucks with these October 2002 engines can significantly reduce emissions. Repowering with October 2002 engines is now allowed under the Carl Moyer Program.

A few districts have also expressed an interest in allowing mechanical-to-electronic engine repowers for heavy-duty on-road vehicles (replacing pre-1987 model year mechanical engines with an October 2002 model year electronic engine). Although this strategy may provide very near-term emission reductions, the fuel and electrical systems are completely different posing some technical and cost-effectiveness challenges. However, staff understands that some districts may wish to fund mechanical-to-electronic engine repowers as a means of achieving immediate emission reductions in order to meet very-near term SIP commitments. Funding will be allowed only on a case-by-case basis. ARB, in cooperation with the local air district, will evaluate the project and determine if the benefits are adequate to merit funding under the Carl Moyer Program. Specific details for on-road heavy-duty engine repowers are presented in Part II of this document.

17. Incentives to Replace Pre-1987 Heavy-Duty Vehicles

The Advisory Board recommended that ARB staff consider including a program to provide incentives to replace pre-1987 heavy-duty diesel vehicles with newer model year vehicles. In the past, a heavy-duty engine retirement program was considered by ARB. However, the analysis indicated that the older, high emitting trucks removed from the fleet were not likely to be replaced with cleaner vehicles, but rather with trucks of similar age from outside the area, providing little or no emission benefit. Also, the prospects for a self-funded program dimmed when the anticipated overseas market for old California trucks did not materialize. Because of the lack of expected emissions benefit and funding, the heavy-duty engine retirement program was never implemented. Many of those same issues are still of concern with the incentive program. ARB staff has conducted ananalysis of the issues and the potential emission benefits of an incentive program and concluded not to incorporate incentives for this program at this time. Appendix A contains staff’s analysis of this program.

18. Project Life for All Project Categories

Based on ARB’s experience with program implementation during the first year, ARB staff provided a specific project life for new purchase versus a repower project to be applied when determining emission benefits and project cost-effectiveness. The project life will be based on the remaining amount of useful life for the older engine. For example, an engine used in a newly purchased heavy-duty line-haul truck has a useful life of about 10 years; hence the selected project life should be 10 years. For a repower project, however, the remaining useful life would be less than 10 years in most cases.

Table 2 below lists the acceptable project life for each project category. The project life is also listed in each chapter under the project criteria.

Table 2
Acceptable Project Life

Project Type	**Repowers (life)**	**New Purchase (life)**
ON-ROAD [a]		
School Buses (≥33,000 GVWR)	N/A	20 years
Buses (≥ 33,000 GVWR)	N/A	12 years
Other	7 years	10 years
OFF-ROAD	7 years	10 years
LOCOMOTIVES	20 years	20 years
FORKLIFTS	N/A	5 years
GSE	N/A	5 years
AGRICULTURAL IRRIGATION PUMPS	7 years	10 years
MARINE VESSELS		
FISHING/OTHER SMALL VESSELS	10 years	10 years
FERRIES/TUGS/LARGE VESSELS	20 years	20 years

Note: a. For on-road, project life may be based on years or the equivalent mileage.

For some project categories the applicant has the option of using a different project life. However, the selected project life must be approved by ARB and the applicant must provide sufficient documentation supporting the project life selected.

E.   Issues

Support for the Carl Moyer Program has been very strong, with the general recognition that the program has been extremely successful and a continued program is needed to meet California's clean air commitments. However, there have been a number of issues raised, which is not surprising given the magnitude of the program and the number of project categories included. This section describes the issues considered during the development of the revisions to the Carl Moyer Program Guidelines. A number of these issues have been resolved, but a few remain controversial.

1. Emission Factors Affect Project Funding for Neighborhood Refuse Haulers

The proposed NOx emission rate for a refuse hauler used in stop-and-go applications, which is defined as a vehicle traveling less than twenty percent of its time above 45 miles per hour, is 4.4 g/bhp-hr. This level represents minimal off-cycle emissions compared to other heavy-duty vehicles. This lower emission factor affects the project cost-effectiveness and thus some refuse hauler projects may only qualify for partial incremental costs. For refuse haulers who may not meet this neighborhood stop-and-go application definition and potentially emit off-cycle emissions, ARB allows applicants to provide drive cycle documentation (such as route and associated speeds) to justify a baseline emission factor that best represents emissions.

2. Dual-Fuel Engines Used in Neighborhood Refuse Haulers May Receive Less Funding

A discount on emission benefits may be necessary for neighborhood refuse haulers using dual-fuel engines. Test data show that while these engines deliver full emission benefits in many applications, the emission benefits are less for engines operated on a low-speed, stop-and-go chassis cycle. Applying a discount on emission benefits would ensure emission benefits are more accurately quantified, while possibly limiting the amount of funds provided to these projects under the program. Prior to funding any dual-fuel project used in a stop-and-go application, the manufacturer must provide the Executive Officer with sufficient in-use documentation to demonstrate that the fuel substitution rate is appropriate to yield the certified benefits.

F. Staff Recommendations

The approved guidelines contain requirements for the Carl Moyer Program. The guidelines establish the basic structure of the program, and the requirements for districts that will be implementing the program locally. The revisions to the guidelines are designed to ensure that the program (for funds distributed in the third year and beyond) continues to achieve real, quantifiable, and enforceable, cost-effective emission reductions. The revisions also include an allocation of third year funds. The allocation will be finalized after districts submit their applications (with requests for funding and commitments to provide matching funds.)

The Board, at its November 16, 2000, hearing, approved:

- New PM requirements, goals, and baselines;
- Districts' new matching fund requirement as recommended by the Advisory Board in March 2000 report;
- Funding allocations;

- Funds to be provided for incremental fuel costs and diesel hybrids on a case-by-case basis;

- Granting the Executive Officer the authority to review actual emission benefits from dual-fuel engines used in low load/high idle applications and apply a discount on emission benefits, if necessary;

- Revised criteria for on-road, off-road, locomotives, marine vessels, agricultural irrigation pump engines, forklifts, and airport GSE;

- New criteria for particulate matter emission reduction requirements and goal, and auxiliary power units for reducing idling emissions from heavy-duty vehicles,

- New emission factors, NOx emission reduction requirement, cost-effectiveness limit, and project life; and

- Continued support of efforts to identify additional funding for the program.

PART II

CARL MOYER PROGRAM GUIDELINES

November 2000

PART II

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CHAPTER I.

PROGRAM REQUIREMENTS

This chapter presents the requirements for districts that wish to administer the Carl Moyer Program locally and issue grants to project applicants. This chapter also lists milestones/due dates for districts implementing the program. The chapter concludes with tentative allocation and disbursement of funding to the districts that apply for funding.

A. Introduction

The Carl Moyer Program will be implemented locally by air pollution control and air quality management districts that choose to participate. Districts must follow the program requirements in this chapter, and must fund projects that meet the criteria in subsequent chapters of these guidelines. The three major program requirements are: 1) the district must provide match funding to receive Carl Moyer Program funding, 2) all projects approved for funding must follow the Carl Moyer Program Guidelines, and 3) all projects funded must meet the cost-effectiveness criterion.

With the exception of some funding designated for ARB administration, all Carl Moyer Program funds will be allocated to participating districts. Districts must apply for funding to administer the program locally. The application form is given in Appendix B.

B. Match Fund Requirements

The total state funding for this program has been $98 million – $25 million for first year, $24 million for the second year, and $50 million for the third year. In the first two years of the program districts provided $1 in match funding for every $2 of Carl Moyer Program funding. The district matching fund requirement is important because it provides a literal “buy-in” from the districts responsible for the selection, monitoring, and enforcement of the project. This requirement helps ensure that the most worthwhile projects are selected.

At the increased funding level in the third year ($50 million) ARB and the Advisory Board recognized that the districts’ ability to provide increased matching funds would be a challenge. The Advisory Board recommended to the Governor and the Legislature that the district matching fund requirement be modified to reflect those required at the $25 million funding level. Subsequently, section 44287 of the Health and Safety Code was amended allowing ARB to modify districts’ matching fund requirement.

The new matching fund requirement is capped at $12 million, following the Advisory Board’s recommendation as described in the Carl Moyer Program Advisory Report dated March 31, 2000. If the level of annual funding for the statewide program is $25 million or less, district matching funds remain at $1 dollar in matching funds for every $2 dollars of Carl Moyer Program Funds received from the ARB. If the annual funding level for the statewide program is greater than $25 million, total matching funds received for the overall program will be $12 million. The formula provided below will be used to determine each district's required matching funds.

$$\frac{\text{district's annual allocation} * \$12{,}000{,}000}{(\text{current annual funding level} \;-\; \text{ARB' administration funds})}$$

The following example is provided to explain how a district's matching funds will be calculated.

EXAMPLE: In the first year, the funding level for the program was $25 million ($24,500,00 for projects and $500,000 for ARB administration) and District X received $11 million. Since the funding level for the program was not more than $25 million, required matching funds would be calculated based on a 2:1 ratio. The required matching funds were:

$11,000,000 / 2 = **$5,500,000** **1st year**

In the second year, the funding level for the program administered by ARB decreased to $19 million ($18,620,000 for projects and $380,000 for ARB administration) and District X received $8,360,000. Since the funding level for the program was not more than $25 million, required matching funds would still be calculated using the 2:1 ratio. District X's required matching funds were:

$8,360,000 / 2 = **$4,180,000** **2nd year**

In the third year, the funding level for the program administered by ARB increased to $45 million ($44,100,000 for projects and $900,000 for ARB administration) and District X is receiving $19 million. Since the funding level for the program is greater than $25 million, required matching funds would be calculated based on the formula listed above. Required matching funds for District X would be:

($19,000,000 * $12,000,000)/($45,000,000 - $900,000) = **$5,170,068 3rd year**

Many districts receive funds from a surcharge on motor vehicle registration fees (a.k.a. AB 2766, AB 434, and AB 4355 funds). Most districts will be using the funds from their motor vehicle fees as match funding for the Carl Moyer Program. In fact, several districts already have active programs to fund grants for lower-emission on-road and off-road motor vehicle projects with the motor vehicle fee money. The Carl Moyer Program funding will augment their programs.

There are some notable differences between district motor vehicle fee funding and the proposed Carl Moyer Program funding: motor vehicle fee funding can be used for refueling infrastructure – the Carl Moyer Program funding cannot. Motor vehicle fee funds cannot be used for marine, locomotive, stationary agricultural irrigation pump, or some off-road projects, while the Carl Moyer Program funds can. These differences made designing the program more challenging. The program allows both sources of funding to be used despite the funding restrictions.

1. Infrastructure Funding

Currently refueling infrastructure can be funded through the Advanced Technology Development and Infrastructure funds administered through the California Energy Commission. In the second and third years of the Carl Moyer Program, the Governor and the Legislature allocated a total of $9 million dollars to fund these portions of the program. Furthermore, any district funds (other than those granted from the California Energy Commission) used to fund refueling infrastructure may count toward the district's required matching funds.

2. Match Funding On An Overall Program Basis

Motor vehicle fee funds must be used for projects that reduce emissions from motor vehicles. Table I-1, below, gives a partial list of motor vehicles and non-motor vehicles. Motor vehicle fee funds cannot be used for locomotives, marine vessels, or stationary agricultural irrigation pump engines.

Carl Moyer Program funds, on the other hand, could be used for on-road vehicles, marine, locomotive, stationary agricultural irrigation pump, off-road, and other approved projects. Districts are allowed to meet their matching fund requirement on an overall program basis, rather than a project-by-project basis. This will allow districts to meet their matching fund requirement by funding motor vehicle projects, and allow districts to use Carl Moyer Program funds for other project categories. The result will be increased flexibility for districts to fund worthwhile clean air projects.

For example, suppose a district is allocated $300,000 in Carl Moyer Program funds. The district spends $150,000 of motor vehicle fee funds (and no Carl Moyer Program funds) for a qualified LNG truck project. The district has met their matching fund requirement, and can spend the $300,000 in Carl Moyer Program funds to repower tugboats (or any other qualifying projects).

Table I-1 Motor Vehicles vs. Non-Motor Vehicles	
Motor Vehicles	**Non-Motor Vehicles**
Automobiles	Locomotives
Trucks	Aircraft
Buses	Lawn mowers (non-riding)
Vans	Leaf blowers
Road graders	Refrigeration units
Earth movers	Chain saws
Tractors	Auxiliary generators
Golf carts	Welding machines
Motorcycles	Pleasure craft
Self-propelled harvesters	Cranes
Forklifts	Marine vessels
Sweepers	Stationary agricultural engines
Motorized Bicycles	Bicycles

3. Tracking Match Funds

If a district is only going to fund motor vehicle projects, the tracking is simple. In the first two years of the program, for every project the district put up $1 in funding for every $2 of Carl Moyer Program funding (a project-by-project match). For third year funding, however, amended section 33287 of the Health and Safety Code allows ARB to modify districts' matching fund requirement if necessary. The new matching fund requirement is capped at $12 million for all districts collectively, following the Advisory Board's recommendations provided in its March 2000 report to the Governor and the Legislature. Districts can fund non-motor vehicle projects even if the only matching funds they have available are motor vehicle fee funds. If that is the case, however, districts must meet the matching fund commitment before they fund a locomotive, marine vessel, or stationary agricultural irrigation pump project.

4. District In-kind Contributions

Districts may use up to 15 percent in-kind contributions (i.e., administrative costs) as matching funds. ARB also believes that it is appropriate for a district to use AB2766 funds as administrative costs to administer the Carl Moyer Program and count as up to 15 percent of a district's required matching funds to implement a local program. Furthermore, a district may fund stationary agricultural irrigation pumps, locomotive, or marine vessel engine projects with Carl Moyer Program project funds, provided that AB2766 funds are used for AB2766 qualifying projects (i.e., on-road heavy-duty vehicles, etc.) that are also Carl Moyer Program qualifying projects. However, under the Health and Safety code Section 44233, districts may not use more than five percent of their AB2766 funds for overall administrative costs.

5. Matching Funds From Other Sources

Section 44286 of the Health and Safety Code allows Port authorities to provide match funding for port projects. Staff believes it is important to have port authorities participate in the program. Port authorities could participate through projects involving their own equipment, or by soliciting port tenants to apply for project funding. To encourage port authority participation, under the current approved program port authorities are allowed to put up match funding for port projects, in lieu of districts. Thus, funding provided by a port authority for a qualifying project, or for associated infrastructure, would count toward the district's matching fund requirement.

Private companies may not provide match funding in lieu of the districts. Staff believes it is appropriate for districts to provide the required matching funds. The requirement that districts provide the matching funds facilitates an equitable distribution of funds, in that it prevents companies with "deep pockets" from tying up the majority of the funds. This requirement also helps ensure that districts carefully evaluate the projects they approve for funding.

C. Cost-Effectiveness

Carl Moyer Program funding plus district match funding may be used for the incremental cost of a project, up to $13,000 per ton of NOx reduced. Only Carl Moyer Program funding, funding under the district's budget authority, or funding provided by a port authority (to meet the matching fund commitment) is included in the cost-effectiveness calculation. Private funding is not included in the cost-effectiveness calculation. Thus, a project that costs more than $13,000 per ton of NOx reduced could be funded, but only if outside funding is used to "buy down" the incremental cost. Funding for infrastructure is not included in the cost-effectiveness calculation. For more detail on what is included in the cost-effectiveness calculation, see the application form in Appendix B.

D. Project Selection

Districts may fund only those projects that comply with the Carl Moyer Program Guidelines, or those projects approved on a case-by-case basis by ARB's Executive Officer. Districts may select which of the qualifying projects to fund based on local priorities. To expedite program implementation, districts may elect to fund qualifying projects on a first come, first served basis. Districts may elect to fund a mix of vehicle, equipment, marine, and locomotive projects. When selecting among competing projects, districts are encouraged to give priority to projects that yield reductions in particulate matter (PM) emissions, as well as the required reductions in NOx emissions. Districts are also encouraged to give priority to the most cost-effective projects.

E. Projects Outside the Scope of the Carl Moyer Program

The Carl Moyer Program is not intended to fund engine research and development, certification testing, operation and maintenance or other “life-cycle” costs, or the cost of operational controls.

F. Monitoring

Districts must monitor the projects they fund to ensure that the expected emission reductions occur. ARB expects that districts would include provisions in their contracts with project applicants requiring the repayment of funds in the event the applicant does not carry out the project as agreed.

G. Reporting

Districts must submit an annual report on the projects funded under this program, so that ARB can track both the NOx and PM emission benefits of the program. In addition, ARB tracks the district’s progress in implementing the program.

By late September of each year, districts must submit a report on their implementation efforts. This implementation report includes: 1) an overview of the application and allocation process; 2) draft project applications, mailout date(s), targeted types of recipients, the number of recipients of each type on the program mailing list (e.g., 23 trucking firms, 14 warehouse distribution centers, 27 farms; 3) names of staff responsible for program implementation; and 4) report on outreach activities (completed and planned).

Districts must report to the ARB annually, by the end of the fiscal year on the Carl Moyer Program. The report must include: 1) a description of projects funded, 2) baseline and incremental project costs, 3) infrastructure funding for qualified vehicle or equipment projects, 4) total state funding obligated under contract, and 5) total district match funding obligated.

H. Timetable With District Milestones

Based on program implementation in the first year, ARB and local district staff found that it is necessary for the program to maintain a consistent schedule. A schedule provides program continuity with milestones for district reporting, initial funding disbursements, and annual guideline revisions. Most importantly, maintaining a schedule allows districts to operate their local programs using consistent guidelines statewide. Since the program is a multi-year program, the revised schedule listed below eliminates any reference to the calendar year.

October – 1st week	Release of the draft revisions to the Carl Moyer Program Guidelines.
November – 3rd week	ARB hearing to consider approval of guidelines.

January – 3rd week	District/port authority applications to administer program due.
February	ARB review of applications to administer program.
March – June	ARB award of grants.
September 30	District report on implementation efforts due.
June 30	One-year district program report on project status due. Districts must report funds that are obligated under contract. Funds that are not obligated may be reallocated to other districts.
June 15	Second-year deadline for districts to have distributed program funds (purchase order issued).
July 31	Second-year district final report on program due.

I. Funding Allocation

In the first three years the Governor and the Legislature appropriated $98 million to fund the Carl Moyer Program. In the first year, fiscal year 1998/1999, the Governor and the Legislature made a one-time appropriation of $25 million to ARB to fund engine projects. In fiscal year 1999/2000, the program was expanded, the Governor and the Legislature made a second one-time appropriation -- $23 million ($19 million to ARB for engine projects and $5 million to CEC for infrastructure and advanced technology). In fiscal year 2000/2001, the Governor and the Legislature made a third one-time appropriation -- $50 million ($45 million to ARB for engine projects, and $5 million to CEC for infrastructure and advanced technology).

In the first two years of the program (Phase I funding cycle and Phase II funding cycle), ARB divided project funds into the following two pots: 1) funds for districts designated as non-attainment with the federal ozone standard; 2) funds for districts in attainment with the federal ozone standard. During these two funding cycles, the amount of funds distributed to each non-attainment district were determined based on a 50/50 weighting of the district population and the benefits of SIP measure M4 in the district's attainment year. For the attainment districts, the amount of funds were determined based on population.

In the third year of the program (Phase III funding cycle), staff has determined a need to slightly modify the method for determining district funding allocations. There are several smaller districts that are now designated as non-attainment, thus increasing the number of non-attainment districts from 9 in the first year to 16 in Phase III. In order to continue providing sufficient funds to the most populated districts and those with very near-term attainment deadlines, funds are still divided into smaller pots. However, these amounts would be based on district contribution to total population, i.e., districts contributing to at least one percent of the total population or having a measure M4 commitment under the 1994 SIP, and districts contributing to less than one percent of the total population.

Project funds are allocated as the follows: 1) 94 percent to large districts (districts with ≥1% of total population or M4 commitment); and 2) Four percent to small districts (districts with <1% of total population).

The tentative allocation for third year funds is shown in Table I-2. Districts may request more than the funding shown. In fact, districts are encouraged to request the maximum funding for which they can commit the required match funds. ARB expects that the total funding requested will exceed the funding available, although it is possible that some districts may request less than their tentative allotment.

ARB will determine the final funding allocation among districts. All funds will be allocated. If any district requests less than their tentative allotment, the remaining funds will be allocated among the districts that requested more than their tentative allotment.

Table I-2
Tentative Funding Allocation

Districts contributing more than 1% of the total population	**Funding Allocation**
Antelope Valley	$ 450,000
Bay Area AQMD	$ 4,306,133
Kern Eastern Desert	$ 450,000
Mojave Desert AQMD	$ 1,535,530
Monterey Bay Unified APCD	$ 450,000
Sacramento Metropolitan AQMD	$ 3,909,604
San Diego County APCD	$ 1,850,344
San Joaquin Valley APCD	$ 7,644,979
Santa Barbara County APCD	$ 450,000
South Coast AQMD	$19,745,849
Ventura County APCD	$ 1,543,561
Subtotal	**$42,336,000**
Districts contributing less than 1% of the total population	$ 1,764,000
ARB 2% administration	$ 900,000
TOTAL	**$45,000,000**

J. Disbursement of Funds

ARB determines the district grant award allocations and issues checks to districts for the initial disbursements. The initial disbursement is 10 percent of the district's allocation, or $100,000 – whichever is greater.

The remaining funds are disbursed on an as needed basis. When a district has contract commitments in place for the initial disbursement plus the required matching funds, the district requests a second disbursement from ARB for an additional 10 percent or what is needed. ARB disburses more than 10 percent of the allocation at a time when a district demonstrates the need based on additional contracts where project funding is imminent. Estimated turnaround time for issuance of checks is three to four weeks from the date ARB receives the request.

K. Reallocation of Funds

ARB encourages districts to implement the program quickly, and to have all the funds obligated via contract within one year. Districts must submit a report on project status by June 30. The report should list projects, state funds spent to date, additional funds obligated via contract, any contracts being negotiated, and remaining state funds that have not yet been obligated.

Any funds not obligated under contract after one year may be reallocated to other districts. Should ARB decide not to reallocate all remaining funds at that time, ARB reserves the right to require periodic progress reports, and to reallocate funding at any time after June 30, if funds are still not obligated under contract.

CHAPTER II.

ON-ROAD HEAVY-DUTY VEHICLES

This chapter presents the project criteria for on-road heavy-duty vehicles under the Carl Moyer Program. It also contains a brief overview of the heavy-duty vehicle industry, NOx emission inventory, current emission standards, available control technology, potential projects eligible for funding, and emission reduction and cost-effectiveness calculation methodologies.

A. Introduction

Vehicles greater than 14,000 pounds gross vehicle weight rating (GVWR) are considered heavy-duty vehicles. Heavy-duty vehicles can be categorized as heavy heavy-duty (HHD) and medium heavy-duty (MHD) vehicles. Heavy heavy-duty vehicles are those greater than 33,000 pounds GVWR and are grouped under a “class 8” truck classification. Medium heavy-duty vehicles are those greater than 14,000 but less than or equal to 33,000 pounds GVWR and comprised of classes 4 through 7 trucks. The majority of all heavy-duty vehicles are powered by diesel engines.

The preference for diesel engines presents an air quality challenge since emissions from diesel engines have not been able to be controlled to the same extent as gasoline vehicles, particularly light- and medium-duty vehicles. Furthermore, heavy-duty diesel vehicles involved in goods movement applications typically accrue higher annual mileage than other vehicles. Consequently, the share of emissions, particularly of NOx and PM, from heavy-duty diesel vehicles is disproportionately higher than their population would suggest. The Carl Moyer Program provides financial incentives to assist in the purchase of cleaner heavy-duty vehicles, including urban buses, to achieve additional near-term emission reductions from these sources.

1. Emission Inventory

In California, on-road mobile sources account for about 50 percent of total NOx emissions. Even though heavy-duty diesel vehicles, including urban buses, account for less than two percent of all on-road vehicles, they emitted about 25 percent of the statewide NOx emissions and over 70 percent of the exhaust PM emissions from all on-road vehicles in 1998. Heavy-duty diesel vehicles emitted 424 tons per day (tpd) of NOx and 26 tpd of exhaust PM emissions statewide. In addition, vehicle miles traveled from heavy-duty vehicles are projected to increase by about 30 percent by 2010. Emissions from heavy-duty diesel vehicles have to be reduced further if air quality goals are to be achieved.

2. Emission Standards

Adopted emission standards have reduced NOx and PM emissions from heavy-duty vehicles substantially. Furthermore, NOx emissions from new heavy-duty vehicles will be cut in half starting in 2004 as a result of recently adopted regulations. Table II-1 lists the existing and future NOx and PM emission standards for heavy-duty engines.

Table II-1
Exhaust Emission Standards for Heavy-Duty Engines

	NOx and PM Emission Standards (g/bhp-hr)[a]			
	Heavy-Duty Vehicles		Urban Buses	
Model Year	**NOx**	**PM**	**NOx**	**PM**
1996 - 2003	--	--	4.0	0.05 [b]
1998 - 2003	4.0	0.10	--	--
2004 +	2.4 [c] or 2.5 [d]	0.10	2.4[c] or 2.5[d]	0.05[b]

[a] g/bhp-hr = grams per brake-horsepower-hour
[b] in-use standard of 0.07 g/bhp-hr
[c] NOx plus Non-Methane Hydrocarbons (NMHC)
[d] NOx plus NMHC with 0.5 g/bhp-hr NMHC cap

The Carl Moyer Program provides incentives to obtain additional emission reductions immediately by encouraging the purchase and deployment of reduced-emission heavy-duty vehicles. Alternative fuel and advanced technology engines can provide significant emission reductions for on-road vehicles. There are several MHD and HHD reduced-emission engine technologies available in the California marketplace.

3. Control Technologies

This section discusses commercially available reduced-emission engines for MHD and HHD vehicles. The engines discussed are considered suitable as new engine/vehicle purchase, or new engine purchases for vehicle repower opportunities. Also discussed briefly are emerging technologies that may be commercially available in two to three years. The information in this section is intended to provide information regarding reduced-emission engine technologies that can be purchased now, and technologies, which have potential to become commercially available in the near term. These technologies are most likely available for the Carl Moyer Program funding. A program criterion for the Carl Moyer Program is that the engines be certified. Some engines discussed below have not been certified to the ARB's optional NOx emission credit standards. However, they are included in this discussion since they could potentially be certified to those standards during the time frame of the Carl Moyer Program.

a. <u>Available Technologies</u>

Diesel engines, due to their high efficiency and long life, dominate the MHD and HHD vehicle market. However, due to their lean-burn operation, they have had limitations in achieving significant NOx emission reductions. Currently, alternative fuel engines, especially compressed natural gas (CNG) and liquefied natural gas (LNG) engines have been able to achieve NOx emissions about half of a conventional diesel engine. In addition to CNG and LNG engines, dual-fuel engines are also available for heavy-duty truck applications. Alternative fuel engines, including liquid petroleum gas (LPG) engines, are also available for medium heavy-duty truck application. Engine manufacturers have invested a considerable amount of resources in the research and development of reduced-emission diesel engines and progress is being made, especially with the integration of advanced electronics and greater use of exhaust gas recirculation. However, it is expected that within the time frame of the Carl Moyer Program, the only new vehicles that will be able to demonstrate the requisite emission reduction will be alternative fuel vehicles.

The variety of alternative fuel engines available, and the number sold, has increased significantly in the past five years. The number and variety of engines continues to expand. Alternative fuel vehicles have made the most progress in the transit bus market. At this time, more than 20 percent of all bus sales in California are alternative fuel and several transit agencies have a policy of exclusively buying alternative fuel buses. These include Sacramento Metropolitan Regional Transit Authority, Los Angeles County Metropolitan Transportation Authority, and Sunline Transit. Current district incentive programs have been instrumental in maturing this market.

Dual-fuel engines are available that are certified to reduce NOx to about 60 percent of the required NOx standards. One set of in-use test data shows that while these engines deliver full emission benefits in many applications, the emission benefits are less for engines operated on a low-speed, stop-and-go chassis cycle (the Central Business District cycle). One indication of this is the percentage of alternative fuel consumed. This fuel substitution rate has been high (approximately 80%) during certification, but may be significantly lower in stop-and-go applications. ARB staff has been working closely with a dual-fuel engine manufacturer to collect additional information and more accurately determine the emission benefits in neighborhood refuse collection. Prior to any dual-fuel project being funded for a stop-and-go application, the manufacturer must provide the Executive Officer with data demonstrating that the fuel substitution rate is appropriate for natural gas versus diesel.

b. Emerging Technologies

Several low-emission technologies hold promise for the future, but are not yet commercially available. Some of these technologies include aqueous fuel, ceramic coating, and high-pressure direct injection natural gas. These technologies may be developed as engine retrofit or new engine technologies, but, at the present time, they are not certified for sale in California to reduced-emission levels. Some of these emerging/experimental technologies may not be able to be certified during the tenure of this program. These technologies would be ineligible to participate in the Carl Moyer Program since the ARB's policy is to provide funding only for reduced-emission engines or technologies that have been certified. However, for very promising technologies that have sufficiently demonstrated their potential to reduce emissions, ARB could grant, on a case-by-case basis, an experimental permit for an engine with certain technology to operate in California. Experimental permits are typically granted for demonstrations involving one or two vehicles, and include very strict limitations. For example, the allowed time for operating a vehicle with an experimental-permitted engine is usually limited to one or two years, after which the engine has to be removed from service, unless an extension is requested and is justified. The ARB intends experimental permits to be a means to field test a technology in some limited situations and not to be a way to circumvent certification requirements.

Even though these emerging technologies may not be commercially available during the current Carl Moyer Program, an on-going incentive program would likely provide the impetus that could expedite the development of these technologies and encourage research and development into additional technologies. Promising longer-term technologies, such as fuel-cell or hybrid powerplants, could potentially qualify for partial funding under the program, if they comply with the program criteria and are certified for sale, or have been granted an experimental permit subject to the limitations discussed above. However, since these technologies are currently too expensive for a project to meet the cost-effectiveness criterion, a cost buy-down would likely be needed.

Alternative Diesel Fuels: Over the years industry has produced various alternative diesel fuels (i.e., diesel water emulsions, bio-diesel, etc.) that may lower PM and NOx emissions from diesel engines, as compared to conventional diesel. Some of these technologies are emerging from the demonstration stage to a commercial product, while others are still in the research stage. As such, ARB staff has been evaluating whether or not to consider alternative diesel fuels that are entering into the commercial market as a potential category for reducing emissions under the Carl Moyer Program.

The Carl Moyer Program is designed to reduce emissions by applying control technology (engine hardware) that has been certified beyond the current standards. In essence, it is a program aimed at providing the end users with an incentive to clean up their very old engines by replacing them with newer engines that have cleaner control technology. Under the current Carl Moyer Program, associated program reductions are easily measured and enforced. Engine technology is typically certified for sale in California by ARB, tested according to regulatory test procedures, and has warranties on components that reduce emissions. Hence the program provides real, quantifiable, and enforceable emission reductions statewide.

Allowing alternative diesel fuel as a category under the Carl Moyer Program may be viable in the future. However, some issues still need to be evaluated by staff before this option is routinely allowed under the Carl Moyer Program. First, allowing this category would require ARB to move from a program that is currently focused on updating old engines (hardware), to a program that would allow diesel engines to remain in operation by simply changing over to an alternative diesel fuel. The manufacturer of the alternative diesel would need to demonstrate that the fuel is cleaner than conventional diesel fuel.

The Carl Moyer program is designed to calculate emission reductions and cost-effectiveness based on actual usage (i.e., mileage, fuel consumption, or hours of operation) and the cost difference between engine technology. Although there may be a cost difference between the alternative diesel fuel and conventional diesel fuel, tracking fuel consumption for the alternative diesel fuel may be difficult. Currently, there is no method for assuring that an alternative diesel fuel is being used over conventional diesel, since vehicles may be able to continue operating on either fuel.

AB 2061, signed by the Governor, appropriated $500,000 to be used for alternative diesel fuels. ARB staff has developed interim test procedures to evaluate the emission benefits of these alternative diesel fuels. Until final procedures are approved, funding for alternative diesel fuel projects will be allowed on a case-by-case basis based on the incremental cost between the two fuels.

Funding for the incremental cost of alternative fuels (if any) will also be allowed on a case-by-case basis. However the alternative fuels must be used with a Carl Moyer qualified project. ARB staff, in cooperation with the district, will evaluate the project to determine whether or not it will qualify for funds based on emission benefits and cost-effectiveness. Furthermore, funding of incremental fuel costs for alternative fuel projects is optional for districts. If funded by the district, these funds would count as a district's matching funds under the Carl Moyer Program.

Hybrid Electric Vehicles: Hybrid buses utilize an electric drive typically with an internal combustion engine (diesel or alternative-fuel) and a traction battery. Current California and federal certification test procedures are based on non-hybrid engine duty-cycles and therefore are not able to adequately represent the emissions benefits of the hybrid technology. Diesel hybrid vehicle projects would only be approved on a case-by-case basis at an emission level deemed appropriate by ARB. ARB staff would determine the emissions benefits for buses based on the chassis Central Business District Cycle. Additional information may be used based on the operating regime of the engine in the particular hybrid system.

c. Incentives for Early Replacement of Pre-1987 Heavy-Duty Vehicles

Pre-1987 heavy-duty diesel trucks still comprise a significant portion of the truck population in California. The engines in these trucks are continuing to be rebuilt since the truck owners/operators typically do not have the financial resources to buy newer trucks. These vehicles typically operate from California's ports to densely populated areas and back. They also operate around-the-clock, and, on a seasonal basis, hauling agricultural products, as well as other non-line haul local deliver applications.

ARB staff understands the need to reduce emissions from this segment of the heavy-duty diesel truck sector. In fact, ARB considered a similar program to retire heavy-duty engines in the past. However, the analysis indicated that the older, high emitting trucks removed from the fleet were not likely to be replaced with cleaner vehicles, but rather with trucks of similar age from outside the area, providing little or no emission benefit. Also, the prospects for a self-funded program diminished when the anticipated overseas market for old California trucks did not materialize. Therefore with the lack of expected emissions benefit and funding, the heavy-duty engine retirement program was never implemented.

Staff conducted another analysis to determine potential benefits associated with providing incentives for the early replacement of pre-1987 heavy-duty engines. This analysis is provided in Appendix A. Based on this analysis, staff was not able to develop a cost-effective program. Therefore, Carl Moyer Program funding is not allowed for the early replacement of pre-1987 heavy-duty vehicles with newer, but used, heavy-duty vehicles.

B. Project Criteria

The project criteria for on-road heavy-duty vehicles provide districts, fleet operators, and transit agencies with the minimum qualifications that must be met for a project to qualify for funding. The main criteria for selecting a project are the amount of emission reductions, cost-effectiveness, and ability for the project to be completed within the timeframe of the program. These criteria will also provide districts and program operators with calculations that must be used for determining emission reductions and cost effectiveness resulting from reduced-NOx on-road heavy-duty vehicle projects. Reduced-NOx on-road heavy-duty vehicle projects, which include new vehicle purchase, vehicle engine replacement (repower), and engine retrofit, will be considered and evaluated for incentive funding. In general, on-road heavy-duty vehicle projects qualifying for evaluation must meet the criteria listed below. The criteria includes new project life for on-road heavy-duty vehicle engine projects based on the remaining amount of useful life for the older engine and is listed for new purchases and repower projects.

- Eligible projects must provide at least 30 percent NOx emission reduction (for new vehicle purchases) compared to baseline NOx emissions. For repower or retrofit projects, the retrofit kit must be certified to reduce NOx emissions by at least 15 percent;

- NOx reductions obtained through this program must not be required by any existing regulations, memoranda of agreement/understanding, or other legally binding documents;

- Reduced-emission engines or retrofit kits must be certified for sale in California and must comply with durability and warranty requirements. Qualified engines could include new ARB-certified engines; ARB-certified aftermarket part engine/control devices; or engines with ARB-approved experimental permits;

- Funded projects must operate for a minimum of 5 years and at least 75 percent of vehicle annual miles traveled must occur in California; and

- Projects must meet a cost-effectiveness criterion of $13,000 per ton of NOx reduced.

- The maximum acceptable project life for calculating on-road project benefits is as follows:

	Default without Documentation	Default with Documentation
School buses $\geq$ 33,000 GVWR – New	20 years	N/A
Buses $\geq$ 33,000 GVWR – New	12 years	N/A
Other On-road – New	10 years	15 years
Other On-road – Repowers	7 years	15 years

Project life beyond the "default without documentation" may be selected for approval by ARB staff. However sufficient documentation must be provided to ARB that supports the selected project life based on the actual remaining useful life.

C. Potential Types of Projects.

The primary focus of the Carl Moyer Program is to achieve emission reductions from heavy-duty vehicles operating in California as early and as cost-effectively as possible. The project criteria were designed to ensure that the emission reductions expected through the deployment of low-emission engines or retrofit technologies under this program are real, quantifiable, and enforceable.

1. New Vehicles

New vehicle purchases of LNG and CNG trucks and buses are expected to be the most common type of project for on-road heavy-duty vehicles under this program. In order to be eligible to participate in this program, the new vehicle/engine has to be certified to one of the ARB's current optional NOx emission credit standards, regardless of fuel type or engine design. The ARB NOx emissions credit standards start at 2.5 g/bhp-hr and decrease in 0.5 g/bhp-hr increments. Engines not certified to the ARB's NOx emission credit standards are not eligible to participate in the Carl Moyer Program even if the engines were certified at levels similar to, or could have been certified at, the credit levels. Table II-2 lists the current heavy-duty engines that have been certified to the ARB's optional NOx emission credit standards. Since new engines are certified throughout the year, districts are encouraged to contact ARB staff for the most current list of eligible engines.

Table II-2
Heavy-Duty Engines Certified to
ARB's Optional NOx Emission Credit Standards
(Emission Levels for NOx, PM, and NMHC are in g/bhp-hr)

MY	Manuf.	Service Type [a]	Fuel Type	Displ (ltr)	NOx	PM	NMHC	Cert. Std. NOx/PM	HP
2000	Baytech	MHD	Dual [b]	5.7	1.3	--	0.00[c]	1.5/NA	211/245[d]
2000	Baytech	MHD	CNG	5.7	1.3	--	0.00	1.5/NA	211
2000	Baytech	HDG	CNG	5.7	1.3	--	0.00	1.5/NA	211
2000	Baytech	HDG	Dual [b]	5.7	1.3	--	0.00[c]	1.5/NA	211/245[d]
2000	Cummins	MHD	LPG	5.9	2.3	0.01	--	2.5/0.10	195
2000	Cummins	MHD	L/CNG	5.9	1.8	0.02	0.1	2.5/0.10	150/195/230
2000	Cummins	HHD	CNG	8.3	1.837	0.02	0.6	2.5/0.10	250/275
2000	Cummins	UB	CNG	8.3	1.7	0.02	0.6	2.5/0.05	250/275
2000	DDC	UB	L/CNG	12.7	2.0	0.02	0.8	2.5/0.05	330
2000	DDC	UB	L/CNG	8.5	1.5	0.01	0.8	2.0/0.05	275
2000	Deere	MHD	CNG	8.1	2.2	0.02	0.4	2.5/0.10	225/250
2000	Deere	MHD	CNG	6.8	2.4	0.04	0.3	2.5/0.10	225
2000	IMPCO	MHD	LPG	7.4	0.8	--	0.66	1.5/NA	229
2000	Mack	HHD	L/CNG	11.9	2.3	0.03	0.3	2.5/0.1	325/350
2000	PSA	MHHD	Dual[e]	7.2	2.2	0.08	1.2	2.5/0.10	200/240/250
2000	PSA	HHD	Dual[e]	10.3	2.4	0.06	1.1	2.5/0.10	305/350
2000	PSA	HHD	Dual[e]	12.0	2.4	0.10	0.5	2.5/0.10	370/410
1999	Deere	MHD	CNG	6.8	2.4	0.04	0.3	2.5/0.10	225
1999	Deere	MHD	CNG	8.1	2.2	0.02	0.4	2.5/0.10	250
1999	DDC	UB	CNG	12.7	2.0	0.02	0.8	2.5/0.05	330
1999	DDC	UB	CNG	8.5	2.2	0.01	0.6	2.5/0.05	275
1999	Cummins	UB	L/CNG	10.0	1.4	0.02	0.03	2.0/0.05	280/300
1999	Cummins	HHD	L/CNG	8.3	1.8	0.02	0.6	2.5/0.10	250/275
1999	Cummins	UB	L/CNG	8.3	1.7	0.01	0.2	2.5/0.05	250/275
1999	Cummins	MHD	L/CNG	5.9	1.8	0.02	0.1	2.5/0.10	150/195/230
1999	Cummins	MHD	LPG	5.9	2.3	0.01	0.8[f]	2.5/0.10	195
1999	IMPCO	MHD	LPG	7.4	0.8	--	0.66	1.5/N/A	229
1999	PSA[g]	MHD	Dual[e]	7.1	2.4	0.09	1.0	2.5/0.10	200
1999	PSA[g]	MHD	Dual[e]	7.2	2.2	0.07	1.2	2.5/0.10	250
1999	PSA[g]	MHD	Dual[e]	7.2	2.4	0.09	1.0	2.5/0.10	200
1999	PSA[g]	HHD	Dual[e]	10.3	2.4	0.06	1.1	2.5/0.10	305/350
1999	PSA[g]	HHD	Dual[e]	12.0	2.4	0.10	0.5	2.5/0.10	370/410

[a] Service Type: MHD (Medium Heavy-Duty); HHD (Heavy Heavy-Duty); UB (Urban Bus)
[b] Dual fuel (CNG or gasoline)
[c] NMHC: 0.00 for CNG; 0.2 for gasoline
[d] Horsepower: 211 for CNG; 245 for gasoline
[e] Dual Fuel (CNG + Diesel; or LNG + Diesel)
[g] Power Systems Associates (using Caterpillar engine)

As evident from Table II-2, only alternative fuel engines are currently certified to the ARB's optional NOx emission credit standard. The Carl Moyer Program is fuel neutral for all project categories. Purchases of new transit buses must be beyond the requirements of ARB's Urban Transit Bus Rule.

2. Repowers

Vehicle repower refers to replacing an older engine with a newer engine certified to lower emission standards. There may be limited opportunities to repower on-road vehicles with new engines. One area where this may be cost-effective to do is in replacing an old mechanical engine with a newer model year mechanical engine that is certified to a lower NOx emission standard. Mechanical engines are those engines having their injection timing mechanically controlled and are most common for pre-1991, and particularly for pre-1987, model year engines. Since certain mechanical engine families share similar engineering designs they could be replaced with another mechanical engine in some cases.

For the purpose of the Carl Moyer Program, eligible heavy-duty diesel-to-diesel truck repower projects are those that replace uncontrolled mechanical engines with emission controlled mechanical engines. For mechanical-to-mechanical engine repowers, an applicant must provide the district with the VIN number, engine model number, and serial number for ARB to determine if the project would qualify for funding. Electronic-to-electronic engine repowers are allowed only when replacing a 1988 and later model year electronic engine with an engine manufactured on or after October 1, 2002. Post 1987 repower projects are allowed for projects where a diesel engine is repowered with an alternative fuel engine.

Under the Carl Moyer Program, funding is not available for projects where spark-ignition engines (i.e., natural gas or gasoline, etc.) are replaced with new diesel engines.

A few districts have expressed an interest to allow mechanical-to-electronic engine repowers for on-road heavy-duty engines. Although substantial NOx emissions may occur by repowering a pre-1987 mechanical engine with an engine manufactured on or after October 1, 2002, the electronically controlled engines are difficult to install in applications that were not previously electronically controlled. The fuel system and electrical system for these engines are completely different compared to a mechanical engine. Mechanical-to-electronic engine repowers are allowed only on a case-by-case basis. ARB, in cooperation with the local air district, will evaluate the project and determine if the benefits are adequate to merit funding under the Carl Moyer Program.

3. Retrofits

Retrofit means making modifications to the engine and/or fuel system such that the retrofitted engine does not have the same specifications as the original engine. Retrofit projects are allowed for all engine model years. The most straightforward retrofit projects are those that could be done at the time of engine rebuild. This might entail upgrading certain engine and/or fuel system components to result in a lower emission configuration. To qualify for funding for these types of projects, the engine retrofit kit must be certified to reduce NOx emissions by at least 15 percent compared to the original engine certification level.

4. Sample Application

In order to qualify for incentive funds, districts make applications available and solicit bids for reduced-emission projects from heavy-duty vehicle operators and transit agencies. A sample application form is included in Appendix C. The applicant must provide at least the following information, as listed in Table II-3.

Table II-3
Minimum Application Information
On-road Projects

1. Air District 2. Applicant Demographics Company Name: Business Type: Mailing Address: Location Address: Contact Number: 3. Project Description Project Name: Project Type: Vehicle Function: Vehicle Class: GVWR(lbs): 4. NOx Reduction Incremental Cost Effectiveness Analysis Basis: (Mileage/Fuel/Hours of Operation) 5. VIN or Serial Number: 6. Application: (Repower, Retrofit or New) 7. NOx Emissions Reductions Baseline NOx Emissions Factor: NOx Conversion Factors Used: Reduced NOx Emissions Factor: Estimated Annual NOx Emissions Reductions: Estimated Lifetime NOx Emissions Reductions: 8. Percent Operated in California:	9. Annual Diesel Gallons Used: 10. Annual Miles Traveled: 11. Hours of Operation: 12. Project Life (years): 13. Old Engine Information Horsepower Rating: Engine Make: Engine Model: Engine Year: 14. New Engine Information Horsepower Rating: Engine Make: Engine Model: Engine Year: Fuel Type: 15. Cost ($) of the Base Engine: 16. Cost ($) of Certified LEV Engine: 17. District Incentive Amount Requested: 18. PM Emissions Reductions Baseline PM Emissions Factor: PM Conversion Factors Used: Reduced PM Emissions Factor: Estimated Annual PM Emissions Reductions: Estimated Lifetime PM Emissions Reductions:

D. Emission Reduction and Cost Effectiveness

1. Emission Reduction Calculation.

In general, the emission reduction benefit represents the difference in the emission level of a baseline and reduced-emission vehicle/engine. In situations where the model year of the vehicle chassis and the model year of the existing engine are different, the model year of the engine will be used to determine the baseline emission factor for emission reduction calculations. The emission level is calculated by multiplying an emission factor, an activity level and a conversion factor, if necessary. Because the conversion factor and the activity level could be different for the baseline and reduced emission vehicle/engine, the emission level should be calculated first and then the difference taken to determine the emission reduction. The examples in the February 1999 Carl Moyer Program Guidelines, where the emission reductions were simply based on the difference in emission factors, assumed that there was no change in the conversion factor or activity level. For most on-road vehicles the activity level is defined by the annual miles traveled as indicated by the vehicle odometer. Refuse vehicles operating in predominantly stop and go applications, however, are the exception. In this case, the activity level should be based on fuel consumed as specified by actual annual fuel receipts or other documentation. Emission reduction calculations shall be consistent with the type of records maintained over the life of the project.

The NOx emission factors have been updated to reflect the recently adopted EMFAC2000 emissions model, which accounts for the settlement agreement between USEPA, ARB and the diesel engine manufacturers (regarding excess NOx emissions from the use of alternative injection timing strategies). EMFAC2000 emission factors are based on chassis dynamometer test data that are in units of g/mile. The model year NOx emission factor listed in Tables II-4, II-5, and II-6 represent the bag 2 zero mile emission factors of medium heavy-duty vehicles, heavy heavy-duty vehicles, and urban buses, respectively. School buses should use the emission factor according to their GVWR.

If annual mileage is the basis for emission reductions, a conversion factor may be needed to convert g/bhp-hr to g/mile units. The conversion factors listed in Table II-7 should be used as default.

Table II-4
NOx Emission Factors for Medium Heavy-Duty Vehicles
14,001 – 33,000 lbs GVWR

Model Year	Grams per Mile
Pre - 1983	18.5
1984 - 1986	17.9
1987 - 1990	15.7
1991 - 1993	13.1
1994 - 1997	11.5
1998 - 2002	10.5
2003 +	5.5

Table II-5
NOx Emission Factors for Heavy Heavy-Duty Vehicles
33,000 + lbs GVWR

Model Year	Grams per Mile
Pre - 1975	28.5
1975 - 1983	27.2
1984 - 1986	20.2
1987 - 1990	16.8
1991 - 1993	16.0
1994 - 1997	19.1
1998	23.0
1999 – 2002	13.4
2003 +	6.7

Table II-6
NOx Emission Factors
for Urban Buses

Model Year	Grams per Mile
Pre – 1987	46.2
1987 – 1990	40.2
1991 – 1993	25.5
1994 – 1995	29.8
1996 – 1998	39.2
1999 – 2002	20.4
2003	10.2
2004 – 2006	2.5
2007	1.0

Table II-7 Diesel Equivalent Conversion Factors for Heavy-Duty Vehicle Projects (bhp-hr/mile)			
Model Year	**Medium Heavy-Duty Diesel 14001-33,000 lbs.**	**Heavy Heavy-Duty Diesel 33000 lbs. +**	**Urban Transit Bus [a] 33000 lbs. +**
Pre-1978	2.3	2.9	4.3
1978 – 1981	2.3	2.8	4.3
1982 – 1983	2.3	2.8	4.3
1984 – 1990	2.3	2.7	4.3
1991 – 1995	2.3	2.7	4.3
1996+	2.3	2.6 [b]	4.3

a. Urban transit buses over 33,000 gross vehicle weight rating (GVWR) or school buses over 33,000 GVWR in an urban area.
b. 2.6 bhp-hr/mile is for all heavy-duty line haul trucks (class 8).

Refuse vehicles operating predominantly in stop-and-go applications accrue low mileage yet intermittently operate at high load during compaction mode. Therefore, a g/mile emission factor may not be appropriate for these operating conditions. Furthermore, based on discussion with engine manufacturers, neighborhood refuse collection trucks are subject to limited off-cycle emissions. ARB staff estimates that a typical heavy-duty diesel truck performing neighborhood waste collection activities would have off-cycle emissions 20 percent of the time. The model year NOx emission factors for refuse vehicles operating predominantly in stop and go applications are listed in Table II-8. An applicant may use the gram per mile emission factors on a case-by-case basis, provided sufficient documentation is provided to ARB showing that the vehicle/fleet do not operate under these conditions.

Table II-8 NOx Emission Factors for Refuse Vehicles Predominantly in Stop-and-Go Applications	
Model Year	**g/bhp-hr**
Pre – 1987	10.0
1987 – 1990	6.0
1991 - 1998	5.2
1999 - 2002	4.4
2003 +	2.5

If annual fuel consumption is the basis for the emission reductions, an energy consumption factor is used to convert g/bhp-hr to g/gallon of fuel used. Heavy-duty diesel engines typically have a brake-specific energy consumption of 6,500 to 7,000 BTU per horsepower-hour on the certification cycle. Diesel fuel has an energy density of about 18,000 BTU/lb and a mass density of 7.0 lb/gallon. This results in an energy consumption factor of about 18.5 horsepower-hour/gallon of fuel consumed, which should be used as the default for refuse vehicles operating predominantly in stop-and-go applications. Otherwise, there are two ways of calculating an engine specific energy consumption factor: 1) divide the horsepower of the engine by the fuel economy in units of gallons/hour or 2) divide the density of the fuel by the brake-specific fuel consumption of the engine. While actual fuel receipts or other documentation support the annual fuel consumption of the baseline engine, the annual fuel consumption of the reduced-emission engine is an estimate proportion to the change in the energy consumption factor. For example, a reduced-emission engine having an energy consumption factor of 18.5, replacing a baseline engine which uses 5,000 gallons/year, and which has an energy consumption factor of 17.8, would have an estimated annual fuel consumption of 5,197 gallons/year. Future fuel receipts or equivalent documentation should be submitted annually, throughout the project life, as verification of this estimate.

New emission factors may prevent some diesel-to-diesel repower projects from qualifying for funding. Therefore, the emission reduction requirement has been modified to 15 percent.

2. Cost-Effectiveness Calculations

For new heavy-duty vehicle purchase projects, only the incremental cost of purchasing a new vehicle that meets the optional NOx emission credit standard compared to a conventional vehicle that meets the existing NOx emission standard, will be funded through the Carl Moyer Program. For vehicle repower projects, the portion of the cost for a vehicle repower project to be funded through the Carl Moyer Program is the difference between the total cost of purchasing and installing the new, emission-certified engine and the total cost of rebuilding the existing engine. For engine retrofit projects, the full cost of the retrofit kit will be funded subject to the $13,000 per ton cost-effectiveness criterion. For Urban Transit Buses, the portion of the capital cost to be funded through the Carl Moyer Program is the non-FTA funds (20 percent of full capital cost) and is subject to the $13,000 per ton cost-effectiveness criterion.

Full incremental cost for an urban transit bus could be granted, however, on a case-by-case basis. The transit district must demonstrate a true need. The transit district would need to provide ARB with its Transportation Implementation Plan (TIP) and any annual updates. If data included in the TIP is not sufficient for ARB to determine the need for the applicant to receive full incremental cost, ARB would ask for additional documentation. The costs that are not considered eligible for Carl Moyer funds include operating costs such as maintenance or other “life-cycle” costs.

Only the amount of money provided by the program and any local district matching fund is to be used in cost-effectiveness calculations. The one-time incentive grant amount is to be amortized over the expected project life (at least five years) and with a discount rate of five percent. The amortization formula (given below) yields a capital recovery factor, which, when multiplied by the initial capital cost, gives the annual cost of a project over its expected lifetime.

Capital Recovery Factor (CRF) = $[(1 + i)^n (i)] / [(1 + i)^n - 1]$

Where,

i = discount rate (5 percent)
n = project life (at least five years)

The discount rate of five percent reflects the opportunity cost of public funds for the Carl Moyer Program. This is the level of earning that could be reasonably expected by investing state funds in various financial instruments, such as U.S. Treasury securities. Cost-effectiveness is determined by dividing the annualized cost by the annual NOx emission reductions. Example calculations for on-road vehicle projects are provided below.

3. Examples

For the purposes of explaining the emission reduction and the cost effectiveness calculations from a heavy-duty engine project, three examples are presented below.

Example 1 – Diesel to Diesel On-Road Repower (Calculations based on Mileage). A line haul trucking company proposes to repower a 1983 heavy heavy-duty diesel line haul truck with a model year 1990 certified NOx diesel engine. This vehicle operates 90% of the time in California.

Emission Reduction Calculation

Baseline NOx Emission factor:	27.2 g/mile
Reduced NOx Emission factor:	16.8 g/mile
Annual Miles:	60,000 miles
% Operated in CA:	90%
Convert grams to tons:	ton/907,200g

Hence, the estimated reductions are:
(27.2 g/mile – 16.8 g/mile) * 60,000 mile/year * 90% * ton/907,200 g =
0.62 tons/year NOx emissions reduced

Cost and Cost-Effectiveness Calculations

The annualized cost is based on the portion of incremental project costs funded by the Carl Moyer Program, any matching funds that were used to fund the project, the expected life of the project (7 years default life for heavy-duty truck repowers), and the interest rate (5 percent) used to amortize the project cost over the project life. The incremental capital cost to the fleet operator for this purchase and the maximum amount that could be funded through the Carl Moyer Program fund are determined as follows:

Incremental Capital Cost:	\$ 30,000 - \$ 7,000 (for rebuild) = \$ 23,000
Maximum Amount Funded:	\$ 23,000
Capital Recovery:	$[(1 + 0.05)^7 (0.05)]/[(1 + 0.05)^7 – 1] = 0.17$
Annualized Cost:	(0.17)(\$ 23,000) = \$ 3,910/year
Cost-Effectiveness:	(\$ 3,910/year)/(0.62 tons/year) **= \$ 6,306/ton**

The cost effectiveness for the example is less than $13,000 per ton of NOx reduced. This project would qualify for the maximum amount of grant funds requested.

Example 2 – Diesel to Diesel On-Road Repower (Calculations based on Mileage). A refuse company proposes to repower a 1970 heavy heavy-duty diesel transfer truck with a model year 1990 certified NOx diesel engine. This vehicle operates 100% of the time in California.

Emission Reduction Calculation

Baseline NOx Emission factor:	28.5 g/mile
Reduced NOx Emission factor:	16.8 g/mile
Annual Miles:	120,000 miles
% Operated in CA:	100%
Convert grams to tons:	ton/907,200g

Hence, the estimated reductions are:

(28.5 g/mile – 16.8 g/mile) * 120,000 mile/year * 100% * ton/907,200 g =
1.5 tons/year NOx emissions reduced

Cost and Cost-Effectiveness Calculations

The annualized cost is based on the portion of incremental project costs funded by the Carl Moyer Program, any matching funds that were used to fund the project, the expected life of the project (7 years default life for heavy-duty truck repowers), and the interest rate (5 percent) used to amortize the project cost over the project life. The incremental capital cost to the fleet operator for this purchase and the maximum amount that could be funded through the Carl Moyer Program fund are determined as follows:

Incremental Capital Cost:	\$ 25,000 - \$ 4,000 (for rebuild) = \$ 21,000
Maximum Amount Funded:	\$ 21,000
Capital Recovery:	$[(1 + 0.05)^7 (0.05)]/[(1 + 0.05)^7 – 1] = 0.17$
Annualized Cost:	(0.17)(\$ 21,000) = \$ 3,570/year
Cost-Effectiveness:	(\$ 3,570/year)/(1.5 tons/year) **= \$ 2,380/ton**

The cost effectiveness for the example is less than $13,000 per ton of NOx reduced. This project would qualify for the maximum amount of grant funds requested.

Example 3 – CNG New Vehicle Purchase (Calculations Based on Fuel Consumption). A refuse collection company proposes to purchase a new CNG vehicle versus a diesel one with a GVWR 58,000 lbs. This vehicle is used for door-to-door refuse pick-up and operates 100% of the time in California.

Emission Reduction Calculation

Baseline NOx Emission factor:	4.4 g/bhp-hr
Reduced NOx Emission factor:	2.5 g/bhp-hr
Conversion Factor:	18.5 bhp-hr/gal
Annual Fuel Consumption:	10,400 gal/year
% Operated in CA:	100 %
Convert grams to tons:	ton/907,200 g

Hence, the estimated reductions are:
(4.4 g/bhp-hr - 2.5 g/bhp-hr) * 18.5 bhp-hr/gal * 10,400 gal/year * 100% * ton/907,200 g =
0.40 tons/year NOx emissions reduced

Cost and Cost-Effectiveness Calculations

The annualized cost is based on the portion of incremental project costs funded by the Carl Moyer Program, any matching funds that were used to fund the project, the expected life of the project (10 years for heavy-duty trucks), and the interest rate (5 percent) used to amortize the project cost over the project life. The incremental capital cost to the fleet operator for this purchase and the maximum amount that could be funded through the Carl Moyer Program fund are determined as follows:

Incremental Capital Cost:	\$ 135,000 - \$ 90,000 = \$ 45,000
Maximum Amount Funded:	\$ 45,000
Capital Recovery:	$[(1 + 0.05)^{10} (0.05)]/[(1 + 0.05)^{10} – 1] = 0.13$
Annualized Cost:	(0.13)(\$ 45,000) = \$ 5,850/year
Cost-Effectiveness:	(\$ 5,850/year)/(0.40 tons/year) **= \$ 14,625/ton**

The cost-effectiveness for the example is greater than the $13,000 per ton cost-effectiveness requirement. In order to meet the $13,000 per ton cost-effectiveness requirement, this project would only qualify for part of the incremental cost – a maximum amount of $40,450.

Example 4 – Urban Bus Purchase. A transit agency proposes to purchase a new CNG bus instead of a new diesel bus. The costs of a CNG bus and a diesel bus are $350,000 and $310,000, respectively. The new bus will operate 100 percent of the time in California.

Emission Reduction Calculation

Baseline NOx Emission factor:	20.4 g/mile
Reduced NOx Emission factor:	2.0 g/bhp-hr
Conversion Factor:	4.3 bhp-hr/mile
Annual Miles:	50,000 miles
% Operated in CA:	100 %

Convert grams to tons: ton/907,200 g

Hence, estimated annual NOx reductions are:
[(20.4 g/mile) – (2.0 g/bhp-hr * 4.3 bhp-hr/mile)] * 50,000 miles/year * 100% * ton/907,200 g =
0.65 tons/year NOx emissions reduced

<u>Cost and Cost-Effectiveness Calculations</u>

The annualized cost is based on the portion of incremental project costs funded by the Carl Moyer Program, any matching funds that were used to fund the project, the expected life of the project (12 years for urban bus), and the interest rate (5 percent) used to amortize the project cost over the project life. For urban bus purchases, the Federal Transit Administration (FTA) pays approximately 80% of the cost of a new transit bus. The incremental capital cost to the transit agency for this purchase and the maximum amount that could be funded through the Carl Moyer Program fund are determined as follows:

FTA Grant for purchase of new diesel bus:	(0.8)($ 310,000) = $ 248,000
Transit agency's cost for new diesel bus:	$ 310,000 - $ 248,000 = $ 62,000
FTA Grant for purchase of new CNG bus:	(0.8)($ 350,000) = $ 280,000
Transit agency's cost for new CNG bus:	$ 350,000 - $ 280,000 = $ 70,000
Incremental Capital Cost:	$ 70,000 - $ 62,000 = $ 8,000
Max. Amount Funded:	$ 8,000
Capital Recovery Factor:	$[(1 + 0.05)^{12} (0.05)]/[(1 + 0.05)^{12} – 1] = 0.11$
Annualized Cost:	(0.11)($ 8,000) = $ 880/year
Cost-Effectiveness:	($ 880/year)/(0.65 tons/year) **= $ 1,354/ton**

The cost effectiveness for the example is less than $13,000 per ton of NOx reduced. This project would qualify for the maximum amount of grant funds requested – the incremental cost of what was not funded by FTA. Once again, full incremental cost for an urban transit bus would be granted, on a case-by-case basis. The transit district must demonstrate a true need by providing ARB with its Transportation Implementation Plan (TIP) and any annual updates. If data included in the TIP is not sufficient for ARB to determine the need for the applicant to receive full incremental cost, ARB would ask for addition documentation. Operating costs such as maintenance or other "life-cycle" costs are not funded under the Carl Moyer Program.

Example 5 – Street Sweeper (Calculations Based on Fuel Consumption). A city municipality proposes to buy a CNG street sweeper in 2001 instead of a diesel street sweeper. The main engine for the proposed street sweeper will be a CNG engine that is certified to the optional NOx standard of 2.5 g/bhp-hr, while the auxiliary engine will be an off-road diesel engine certified to a NOx standard of 6.9 g/bhp-hr. This vehicle is operated entirely within the city's limit in California. Based on historical fuel usage, the main engine of the street sweeper uses approximately two-thirds of the total fuel consumed with the remaining one-third attributable to the auxiliary engine. The cost of a new CNG street sweeper is $162,000 compared to $122,000 for a new diesel powered street sweeper

Emission Reduction Calculation

Baseline NOx Emission factor:	4.4 g/bhp-hr
Reduced NOx Emission factor:	2.5 g/bhp-hr
Conversion Factor:	18.5 bhp-hr/gal
Annual Fuel Consumption:	5,300 gal/year
% Operated in CA:	100 %
Convert grams to tons:	ton/907,200 g

Hence, the estimated reductions are:

Main Engine:

(4.4 g/bhp-hr - 2.5 g/bhp-hr) * 18.5 bhp-hr/gal * 5,300 gal/year *(2/3)* 100% * ton/907,200 g = **0.14 tons/year NOx emissions reduced**

Auxiliary Engine:

(6.9 g/bhp-hr – 6.9 g/bhp-hr) * 18.5 bhp-hr/gal * 5,300 gal/year *(1/3)* 100% * ton/907,200 g = **0 ton/year NOx emissions reduced**

Total Emission Reductions: 0.14 + 0 = 0.14 tons/year NOx emiss. reduced

Cost and Cost-Effectiveness Calculations

The annualized cost is based on the portion of incremental project costs funded by the Carl Moyer Program, any matching funds that were used to fund the project, the expected life of the project (10 years for heavy-duty trucks), and the interest rate (5 percent) used to amortize the project cost over the project life. The incremental capital cost to the fleet operator for this purchase and the maximum amount that could be funded through the Carl Moyer Program fund are determined as follows:

Incremental Capital Cost:	\$ 162,000 - \$ 122,000 = \$ 40,000
Maximum Amount Funded:	\$ 40,000
Capital Recovery:	$[(1 + 0.05)^{10} (0.05)]/[(1 + 0.05)^{10} – 1] = 0.13$
Annualized Cost:	(0.13)(\$ 40,000) = \$ 5,200/year
Cost-Effectiveness:	(\$ 5,200/year)/(0.14 tons/year) **= \$ 37,143/ton**

The cost-effectiveness for the example is greater than the \$13,000 per ton cost-effectiveness requirement. In order to meet the \$13,000 per ton cost-effectiveness requirement, this project would only qualify for part of the incremental cost – a maximum amount of \$12,924.

E. Reporting and Monitoring.

The district has the authority to conduct periodic checks or solicit operating records from the applicant that has received Carl Moyer funds for new heavy-duty vehicle purchase, vehicle repowering, or engine retrofit projects. This is to ensure that the vehicle or engine is operated as stated in the program application. Fleet operators and transit agencies participating in the Carl Moyer Program are required to keep appropriate records during the life of the funded project. Records must contain, at a minimum, total miles traveled and California miles traveled, amount of fuel used, and maintenance and repair information. Records must be retained and updated throughout the project life and made available at the request of the district.

CHAPTER III.

OFF-ROAD EQUIPMENT

This chapter presents the project criteria for off-road equipment projects under the Carl Moyer Program. It also contains a brief overview of the current emission standards, available control technology, potential incentive projects eligible for funding, and emission reduction calculation and cost-effectiveness calculation methodologies.

A. Introduction

Off-road engines are used in a wide array of applications, including, but not limited to, agricultural tractors, backhoes, excavators, trenchers, and motor graders. Off-road equipment can be further split into two broad categories: less than 175 horsepower and equal to or greater than 175 horsepower. The ARB is preempted from regulating new farm and construction equipment less than 175 horsepower; the USEPA has sole authority to control equipment in this category. ARB has the authority to regulate off-road equipment equal to or greater than 175 horsepower and non-preempted off-road equipment less than 175 horsepower.

Off-road equipment eligible for funding under the Carl Moyer Program includes equipment 50 horsepower or greater. Excluded from this discussion are engines that propel or are used on aircraft, locomotives, and marine vessels. Engines used in locomotive and marine vessel applications are discussed in Chapters IV and V, respectively, and aircraft engines are excluded from the Carl Moyer Program. Also excluded from this discussion are engines used in forklifts and airport ground support equipment. These two off-road categories are discussed separately in Chapters VII and VIII, respectively. This program does not apply to off-road engines used for underground mining operations and are regulated by the Mining Safety and Health Administration.

1. Emission Standards

Emissions from off-road equipment were uncontrolled prior to 1996. Estimates of NOx emission levels from uncontrolled off-road engines range from 8.3 g/bhp-hr to 18 g/bhp-hr. In January 1992, ARB adopted exhaust emission standards for off-road diesel cycle engines 175 horsepower and greater to be effective starting with the 1996 model year engines. Table III-1 lists ARB's existing and future NOx and PM emission standards for off-road diesel cycle engines.

Table III-1 ARB Exhaust Emission Standards for Heavy-Duty Off-Road Engines						
Rated Power (horsepower)	**NOx and PM Emission Standards (g/bhp-hr)**					
	1996		**2000**		**2001**	
	NOx	PM	NOx	PM	NOx	PM
175 $\leq$ hp $\leq$ 750	6.9	0.4	--	--	5.8	0.16
> 750 hp	--	--	6.9	0.4	--	--

The USEPA has adopted virtually identical NOx emission standards for off-road diesel cycle engines at or above 50 horsepower. The USEPA rule aligns with California's first tier regulations for engines 175 horsepower and greater and took effect in 1996. The USEPA rule also took effect in 1997 for off-road diesel cycle engines at or above 100 horsepower but less than 175 horsepower and in 1998 for off-road diesel cycle engines at or above 50 horsepower but less than 100 horsepower. The combination of ARB and USEPA emission standards means that all of today's new off-road diesel cycle engines 50 to 750 horsepower have to be certified to meet a NOx emission standard of 6.9 g/bhp-hr. Table III-2 lists USEPA's existing and future NOx and PM emission standards for off-road diesel cycle engines.

Table III-2 USEPA Exhaust Emission Standards for Off-Road Diesel Engines								
Rated Power (horsepower)	**NOx and PM Emission Standards (g/bhp-hr)**							
	1996		**1997**		**1998**		**2000**	
	NOx	PM	NOx	PM	NOx	PM	NOx	PM
50 $\leq$ hp < 100	--	--	--	--	6.9	--	--	--
100 $\leq$ hp < 175	--	--	6.9	--	--	--	--	--
175 $\leq$ hp < 750	6.9	0.4	--	--	--	--	--	--
$\geq$ 750 hp	--	--	--	--	--	--	6.9	0.4

USEPA, ARB, and off-road diesel engine manufacturers have signed a Statement of Principles (SOP) that sets forth comprehensive future emission standards for compression ignition (diesel) off-road engines. The SOP provides for new NOx, PM, and carbon monoxide (CO) emission standards for engines with different horsepower ratings to be effective in a tiered approach. The SOP's Tier 1 NOx emission levels for off-road diesel engines 50 horsepower and greater are the same as the ARB's NOx emission standards for off-road diesel cycle engines 175 horsepower or greater, as discussed previously. Starting with model year 2001 engines, the SOP provides for a combined NOx and non-methane hydrocarbon (NMHC) emission levels for off-road engines in this category ranging from 4.8 g/bhp-hr to 5.6 g/bhp-hr (NOx + NMHC). The Tier 2 NOx + NMHC emission levels for off-road diesel engines 50 horsepower and greater will be reduced further with the incorporation of the Tier 3 emission levels, ranging from 3.0 g/bhp-hr to 3.5 g/bhp-hr NOx + NMHC, starting in 2006. USEPA has adopted regulations for off-road diesel equipment consistent with the emission levels contained in the SOP. The ARB intends to revise California's regulations for off-road equipment to harmonize with federal regulations.

The Carl Moyer Program is intended to provide additional emission reductions immediately by encouraging the purchase of eligible new off-road equipment, or emission-certified off-road engines to replace eligible uncontrolled engines. This program also applies to projects that repower emission-certified equipment with engines certified to an optional NOx emission credit standard. Grants from the Carl Moyer Program can be used for the purchase of eligible retrofit kits that reduce NOx emissions from uncontrolled engines to the 6.9 g/bhp-hr NOx emission standard, or lower. Carl Moyer Program grants can also be used for the purchase of retrofit kits that reduce NOx emissions by at least 15 percent from eligible emission-certified engines.

2. Control Technologies

The purpose of this section is to discuss reduced-emission engines for off-road equipment that are commercially available. The engines discussed are considered suitable as new equipment purchase, or new engine purchase for repower opportunities. Emerging technologies that may be commercially available in two to three years are also discussed. There is no discussion of technologies considered to be in the experimental or pre-prototype category. This section is intended to provide information regarding reduced-emission engine technologies that can be purchased now, and technologies, which have potential to become commercially available in the very near term.

a. Available Technologies

Emission-Certified Engines. Currently, off-road diesel cycle engines 50 horsepower and greater must to comply with a NOx emission standard of 6.9 g/bhp-hr. The NOx emission standard for off-road diesel cycle engines 175 to 750 horsepower sold in California will be reduced to 5.8 g/bhp-hr for the model year 2001 engines. As discussed previously, these standards do not apply to engines used in aircraft, locomotive, or marine vessel applications.

A viable and cost-effective way to reduce emissions from pre-controlled equipment is to replace the engine in that equipment (i.e., repower) with an emission-certified engine instead of rebuilding the existing engine to its original uncontrolled specifications. Although this is commonly a diesel-to-diesel repower, significant NOx and PM benefits may be achievable due to the high emission levels of the uncontrolled engine being replaced. Emission-certified engines are commercially available for off-road engines 50 horsepower and greater that are covered under this program. Off-road equipment comes in a vast array of sizes, weights, and power requirements. Therefore, a particular engine may be suitable for one application but not another. Another option, which may be possible for some situations, is to replace an off-road engine with a new or rebuilt on-road engine certified to a NOx emission standard of 6.9 g/bhp-hr or lower. It may be possible, in some cases, to replace an older uncontrolled diesel engine with a newer emission-certified alternative fuel engine. Even though diesel-to-alternative fuel repower projects for off-road equipment are eligible for funding under the Carl Moyer Program, they are not expected to be as common as diesel-to-diesel repower projects.

Off-Road Engine Retrofit Technology. Retrofit technology options for off-road diesel engines to reduce NOx emissions from uncontrolled levels to the existing 6.9 g/bhp-hr NOx emission standard, or lower, are limited. Any retrofit technology must be certified for sale in California, must be able to reduce NOx emissions by at least 15 percent, and must comply with established durability and warranty requirements. It is possible that retrofit technologies that have been used to reduce NOx and PM emissions from on-road heavy-duty diesel engines could be used to control off-road engine emissions in some applications.

b. Emerging Technologies

Several reduced-emission technologies hold promise for the future, but are not yet commercially available. These technologies are being developed for on-road heavy-duty diesel engines, but they can be used in off-road diesel engine applications as well. Some of these technologies include: aqueous fuel, ceramic coating, and high pressure direct injection natural gas. These technologies may be developed as engine retrofit or new engine technologies, but at the present time, they are not certified for sale in California. Some of these emerging and/or experimental technologies may not be able to be certified during the tenure of this program. These technologies would be ineligible to participate in the Carl Moyer Program since the ARB's policy is to provide funding only for reduced-emission engines or technologies that have been certified. However, for very promising technologies that have sufficiently demonstrated their potential to reduce emissions, ARB could grant, on a case-by-case basis, an experimental permit for an engine with certain technology to operate in California. Experimental permits are allowed for only one or two engine demonstrations and are granted with very strict limitations. For example, the allowed time for operating equipment with an experimental-permitted engine is usually limited to one or two years, after which the engine has to be removed from service, unless an extension is requested and is justified. The ARB intends experimental permits to be a means to field test a technology in some limited situations and not to be a way to circumvent certification requirements.

B. Project Criteria

The project criteria have been designed to provide districts and equipment operators with a list of minimum qualifications that must be met in order for an off-road equipment project to qualify for funding. The main criteria for selecting a project are: the amount of emission reductions, cost-effectiveness, and ability for the project to be completed within the timeframe of the program. The criteria also establish a method for calculating emission reductions and cost-effectiveness for reduced-NOx off-road equipment projects. Reduced-NOx off-road equipment projects that include equipment repowers or engine retrofits will be considered and evaluated for incentive funding. In general, off-road equipment projects qualifying for evaluation must meet the following criteria:

- For new equipment purchase, the new engine must be certified to an ARB optional NOx emission credit standard for off-road diesel equipment that is at least 30 percent lower than the existing NOx emission standard.

- For equipment repower projects the replacement engine must be certified to a NOx emission standard that is at least 15 percent lower than the current ARB NOx emission standard;

- For engine retrofit projects: (i) the retrofit kit must be certified to reduce NOx emissions to 6.9 g/bhp-hr, or lower, if it is used to retrofit an eligible uncontrolled engine, or (ii) the retrofit kit must be certified to reduce NOx emissions by at least 15 percent if it is used to retrofit eligible emission-certified engines;

- Reduced-emission engines or retrofit kits must be certified for sale in California and must comply with durability and warranty requirements. Qualified engines could include new ARB-certified engines; ARB-certified aftermarket part engine/control devices; or engines with ARB-approved experimental permits;

- NOx reductions obtained through this program must not be required by any existing regulations, memoranda of understanding/agreement, or other legally binding documents;

- Funded projects must operate for a minimum of 5 years and at least 75 percent of equipment hours of operation must occur in California;

- The acceptable maximum project life for calculating benefits from off-road projects is as follows:

	Default without Documentation	Default with Documentation
Off-road New	10 years	15 year
Off-road Repower	7 years	15 years

A different project life may be selected for approval by ARB staff. However sufficient documentation must be provided to ARB that supports the selected project life based on the actual remaining useful life.

- Projects must meet a cost-effectiveness criterion of $13,000 per ton of NOx reduced.

C. Potential Types of Projects

The primary focus of the Carl Moyer Program is to achieve emission reductions from off-road diesel engines and equipment operating in California as early and as cost-effectively as possible. The project criteria are designed to ensure that the emission reductions expected through the deployment of reduced-emission engines or retrofit technologies under this program are real, quantifiable, and enforceable. A project must meet a cost-effectiveness criterion of $13,000 per ton of NOx reduced, and/or subject to a maximum dollar amount to be granted based on the horsepower ratings of the engine. The project must be operated for at least five years from the time it is first put into operation and at least 75 percent of the hours of operation must occur in California.

1. Purchase of New Emission-Certified Engines

New off-road engines, 50 horsepower or greater, are required to be certified to a NOx emission standard of 6.9 g/bhp-hr. In addition to the 6.9 g/bhp-hr NOx emission standard, the ARB has adopted optional NOx emission credit standards for off-road equipment that start at 5.0 g/bhp-hr and decrease in 0.5 g/bhp-hr increments. Starting in 2001, the NOx emission credit standards for off-road diesel equipment will start at 4.5 g/bhp-hr and also decrease in 0.5 g/bhp-hr increments. The Carl Moyer Program funds the incremental cost of buying new off-road equipment certified to an optional NOx emission credit standard compared to the cost of buying a new off-road equipment certified to the current NOx emission standard. Even though off-road engines certified to an optional NOx emission credit standard are not available now, they may become available during the life of the Carl Moyer Program.

For some off-road equipment (i.e., yard hostlers, yard goats) it may be possible to design the equipment with specifications to power the equipment with a new on-road engine certified to an optional NOx emission credit standard instead of a new off-road equipment engine. Where this is the case, emission benefits from the baseline engine would be calculated based on an on-road engine. If an applicant provides ARB with documentation showing that past practices (the current fleet) is predominantly yard hostlers powered with off-road engines, then an off-road engine emission factor baseline would be used.

2. Repower with Emission-Certified Engines

Purchases of new emission-certified engines to replace uncontrolled engines in existing equipment are expected to be the most common type of project for off-road diesel equipment under this program. Eligible off-road equipment repower projects refers to replacing an older uncontrolled engine with a newer engine certified to either the existing NOx emission standard or to an optional NOx emission credit standard for off-road diesel equipment.

Eligible off-road equipment repower projects also refer to replacing an emission certified engine with a newer engine certified to an optional NOx emission credit standard. Another option, which may be possible for some situations, is to repower off-road diesel equipment with a new or rebuilt on-road engine certified to NOx emission standard of 6.0 g/bhp-hr or lower. In addition, ARB could grant, on a case-by-case basis, an experimental permit for a particular engine with certain technology to operate in California. Funding under the Carl Moyer program is not available to pay for projects where a spark-ignition engine (i.e., natural gas, gasoline, etc.) is replaced with a diesel engine.

Off-road equipment repower projects that replace an existing diesel engine with an eligible reduced-emission diesel engine (either off-road or on-road) are no longer subject to a maximum grant amount awarded, based on the horsepower category of the engine. Based on ARB and district's experience with the first year of the program the grant award caps that were placed on this project category prevented some projects for construction and agricultural equipment from being funded. These project subcategories typically use large equipment with engines that cost above the grant award caps. Funding for off-road repower projects will be based on the cost-effectiveness limit.

The emission factors under section D of this chapter have been revised to account for the new OFFROAD model. The new emission factors may prevent some diesel-to-diesel repower projects from qualifying for funding. Hence the emission reduction requirement for repowers and retrofits, has been modified to 15 percent.

3. Retrofits

Retrofit means making modifications to the engine and/or fuel system such that the retrofitted engine does not have the same specifications as the original engine. Retrofit projects may be applicable to certain off-road diesel engine families. The most straightforward retrofit projects are those that could be accomplished at the time of engine rebuild. This might entail upgrading certain engine and/or fuel system components to result in a lower emission configuration. It is possible that retrofit technologies that have been used to reduce NOx and PM emissions from on-road heavy-duty diesel engines could be used to control off-road engine emissions in some applications. To qualify for funding, the engine retrofit kit must be certified to reduce

NOx emissions to 6.9 g/bhp-hr, or lower, if it is used to retrofit an eligible uncontrolled engine. The Carl Moyer Program grants will also apply to retrofit kits that reduce NOx emissions from emission-certified engines by at least 15 percent.

Staff revised emission factors under section D of this chapter to account for the new OFFROAD model. The new emission factors may prevent some diesel-to-diesel retrofit projects from qualifying for funding. So the minimum emission reduction requirement for repower and retrofit projects has been modified to allow funding for projects that meet a 15 percent emission reduction requirement.

4. Sample Application

In order to qualify for incentive funds, districts will make applications available and solicit bids for reduced-emission projects from off-road diesel equipment operators. A sample application form is included in Appendix D. The applicant must provide at least the following information, as listed in Table III-3.

Table III-3 Minimum Application Information Off-road Projects	
1. Air District: 2. Applicant Demographics Company Name: Business Type: Mailing Address: Location Address: Contact Number: 3. Project Description Project Name: Project Type: Equipment Function: 4. NOx Reduction Incremental Cost Effectiveness Analysis Basis: (Mileage/Fuel/Annual Hours) 5. VIN or Serial Number: 6. Application: (Repower, Retrofit or New) 7. Percent Operated in California: 8. Annual Diesel Gallons Used: 9. Annual Miles Traveled: 10. Hours of Operation: 11. Project Life (years):	12. Old Engine Information Horsepower Rating: Engine Make: Engine Model: Engine Year: 13. New Engine Information Horsepower Rating: Engine Make: Engine Model: Engine Year: Fuel Type: 14. NOX Emissions Reductions Baseline NOx Emissions Factor (g/bhp-hr): NOx Conversion Factors Used: Reduced NOx Emissions Factor (g/bhp-hr): Estimated Annual NOx Emissions Reductions: Estimated Lifetime NOx Emissions Reductions: 15. Cost ($) of the Base Engine: 16. Cost ($) of Certified LEV Engine: 17. PM Emissions Reductions Baseline PM Emissions Factor (g/bhp-hr): PM Conversion Factors Used: Reduced PM Emissions Factor (g/bhp-hr): Estimated Annual PM Emissions Reductions: Estimated Lifetime PM Emissions Reductions: 18. District Incentive Amount Requested:

D. Emission Reduction and Cost-Effectiveness

1. Emission Reduction Calculation

In general, the emission reduction benefit represents the difference in the emission level of a baseline and reduced-emission engine. Emission factors for the baseline engines are listed in Table III-4. These emission factors reflect the recently adopted emissions inventory for off-road large compression-ignited engines, greater than or equal to 25 horsepower. The OFFROAD model incorporated recent data and reflects currently adopted regulations. Engine manufacturers applied some of the technology advancements in the fuel management systems used in 1988 and newer on-road diesel-powered engine to similar off-road engines. The applicant does have the option of testing the uncontrolled engine using an ARB approved test procedure to determine actual emissions. The maximum allowable baseline emissions for pre-1996 engines as determined through in-use testing is 13 g/bhp-hr ($\leq$120 hp) and 11 g/bhp-hr (>120 hp).

Table III-4
Baseline NOx Emission Factors for
Uncontrolled Off-Road Heavy-Duty Diesel Engines (g/bhp-hr)

Model Year	50 –120 hp	120 + hp
Pre - 1988	13	11
1988 – 1996	8.75	8.17

In situations where the model year of the equipment and the model year of the existing engine are different, the model year of the engine will be used to determine the baseline emission factor for emission reduction calculations. For off-road equipment (i.e., yard hostlers, yard goats) designed with specifications to power the equipment with a new on-road engine certified to an optional NOx emission credit standard instead of a new off-road equipment engine, emission benefits from the baseline engine will be based on an on-road engine. If an applicant provides ARB with documentation showing that past practices (the current fleet) is predominantly yard hostlers powered with off-road engines, then an off-road engine emission factor baseline can be used. The emission level is calculated by multiplying an emission factor, a conversion factor and an activity level. Because the conversion factor and the activity level could be different for the baseline and reduced emission engine, the emission level should be calculated first and then the difference taken to determine the emission reduction. The examples in the February 1999 Carl Moyer Program Guidelines, where the emission reductions were simply based on the difference in emission factors, assumed that there was no change in the conversion factor or activity level. For off-road equipment, the activity level is either the annual hours of operation or fuel consumed. Emission reduction calculations would be consistent with the type of records that would be maintained over the life of the project.

If the annual hours of operation are the basis for determining the emission reductions, the conversion factor is the horsepower of the engine multiplied by the load factor of the application and the activity level should be based on the actual hours of the equipment. The load factor is an indication of the amount of work done, on average, by an engine for a particular application, given as a fraction of the rated horsepower of the engine. The load factor is different for each application. If the actual load factor is known for an engine application, it should be used in calculating the emission reductions. If the load factor is not known, the proposed default values provided below should be used. Another variable in determining the emission reductions is the number of hours that the equipment operates a year. If the equipment is not outfitted with an hour meter then the hours of operation may not be used for calculating emission reductions. The hour meter is the required instrument for the applicant to use when providing a district with estimated annual hours of operation. The adopted OFFROAD emission inventory model reflects load factors from 0.43 to 0.78 for both heavy-duty diesel engines in agricultural and construction applications. The default load factor for off-road equipment in agricultural and construction applications is:

Default Load factor for
Agricultural and Construction Equipment: 0.43

If the annual fuel consumption is used, an energy consumption factor should be calculated and the activity level should be based on actual annual fuel receipts or other documentation. The energy consumption factor converts the emission factor in terms of g/bhp-hr to g/gallon of fuel used. There are two ways of calculating the energy consumption factor: 1) by dividing the horsepower of the engine by the fuel economy in units of gallons/hour or 2) by dividing the density of the fuel by the brake-specific fuel consumption of the engine. While actual fuel receipts support the annual fuel consumption of the baseline engine, the annual fuel consumption of the reduced-emission engine is an estimate proportion to the change in the energy fuel consumption factor. For example, a reduced-emission engine having an energy consumption factor of 20, replacing a baseline engine which uses 3,696 gallons/year and has an energy consumption factor of 18.5, would have an estimated annual fuel consumption of 3,419 gallons/year. Future fuel receipts or equivalent documentation should be submitted, throughout the project life, as verification of this estimate.

2. Cost-Effectiveness Calculation

The portion of the cost for a repower project to be funded through the Carl Moyer Program is the difference between the total cost of purchasing and installing the new, emission-certified engine and the total cost of either rebuilding the existing engine or the cost of buying a "conventional" replacement engine.

Only the amount of money provided by the Carl Moyer program and any local district match funds can be used in the cost-effectiveness calculations. The one-time incentive grant amount is to be amortized over the expected project life (at least five years) with a discount rate of five percent. The amortization formula (given below) yields a capital recovery factor, when multiplied with the initial capital cost, gives the annual cost of a project over its expected lifetime.

Capital Recovery Factor (CRF) = $[(1 + i)^n (i)] / [(1 + i)^n - 1]$

Where, i = discount rate (5 percent)
n = project life (at least five years)

The discount rate of five percent reflects the opportunity cost of public funds for the Carl Moyer Program. This is the level of earning that could be reasonably expected by investing state funds in various financial instruments, such as U.S. Treasury securities. Cost-effectiveness is determined by dividing the annualized cost by the annual NOx emission reductions. Example calculations for off-road equipment projects are provided below.

3. Examples

For the purposes of explaining the emission reduction and the cost effectiveness calculations from a particular off-road equipment project, two examples are presented below. The first example describes the calculations based on hours of operation, whereas, the second example describes the calculations based on fuel consumption.

Example 1 – Construction Equipment Repower (Calculations Based on Hours of Operation). An equipment owner applies for a Carl Moyer Program grant for the purchase of a new off-road diesel engine rated at 180 hp to replace a 1985 uncontrolled diesel engine rated at 150 hp used in a construction loader. The owner does not know the load factor for this application. Both the old and new engine will operate 700 hours annually and 100 percent of the time in California. The cost of the new emission-certified diesel engine is $13,400 whereas the cost to rebuild the old engine would be $8,000. Installation and re-engineering cost (to install the new engine into the existing equipment) is $3,000.

<u>Emission Reduction Calculation</u>

Baseline NOx Emission Factor:	11 g/bhp-hr
Reduced NOx Emission Factor:	6.9 g/bhp-hr
Baseline Horsepower:	150 hp
Reduced Horsepower:	180 hp
Baseline Load Factor:	0.43
Reduced Load Factor:	0.36
Annual Hours of Operation:	700 hours
% Operated in CA:	100%

Hence, the estimated reductions are:
[(11 g/bhp-hr * 0.43 * 150 hp) – (6.9 g/bhp-hr * 0.36 * 180 hp)] * 700 hrs/year * 100% * ton/907,200 g = **0.20 tons/year NOx emissions reduced**

<u>Cost-Effectiveness Calculations</u>

The annualized cost is based on the portion of incremental project costs funded by the Carl Moyer Program, the expected life of the project (7 years default life), and the interest rate (5 percent) used to amortize the project cost over the project life. The incremental capital cost to the equipment owner for this purchase and the maximum amount that could be funded through the Carl Moyer Program fund are determined as follows:

Total installed cost of new engine:	$ 13,400 + $ 3,000 = $ 16,400
Incremental Capital Cost:	$ 16,400 - $ 8,000 = $ 8,400
Max. Amount Funded:	$ 8,400
Capital Recovery:	$[(1 + 0.05)^7 (0.05)]/[(1 + 0.05)^7 – 1] = 0.17$
Annualized cost:	(0.17)($ 8,400) = $ 1,428/year
Cost-Effectiveness:	($ 1,428/year)/(0.20 tons/year) **= $ 7,140/ton**

The project meets the cost-effectiveness limit of $13,000 per ton NOx reduced and would qualify to receive the entire incremental cost ($8,400).

Example 2 – Agricultural Harvester Repower (Based on Fuel Consumption). An equipment owner applies for a Carl Moyer Program grant for the purchase of a new off-road diesel engine (2000, 170 hp, 6.9 g/bhp-hr NOx) to replace an uncontrolled diesel engine (1980, 200 hp, 11 g/bhp-hr NOx) used in a harvester. The installed cost of the new emission-certified diesel engine is $9,500, whereas, the cost to rebuild and install the old engine would be $6,900. The new engine will use 4,600 gallons of diesel fuel annually and will operate 100 percent of the time in California.

Emission Reduction Calculation

Baseline NOx Emissions:	11.0 g/bhp-hr
Baseline Energy Consumption Factor:	18.5 hp-hr/gal
Baseline Annual Fuel Consumed:	4,600 gallons
Reduced NOx Emissions:	6.9 g/bhp-hr
Reduced Energy Consumption Factor:	21.8 hp-hr/gal
Reduced Annual Fuel Consumed:	3,904 gallons
% Operated in CA:	100%
(ton/907,200 g):	Converts grams to tons

Hence, estimated annual NOx reductions are:
[(11.0 g/bhp-hr * 18.5 bhp-hr/gal * 4,600 gal/yr) – (6.9 g/bhp-hr * 21.8 hp-hr/gal * 3,904 gal/yr)] * 1.0 * ton/907,200 g = **0.38 tons/year**

Cost-Effectiveness Calculations

The annualized cost is based on the portion of incremental project costs funded by the Carl Moyer Program, the expected life of the project (5 years at a minimum), and the interest rate (5 percent) used to amortize the project cost over the project life. The incremental capital cost to the fleet operator for this purchase and the maximum amount that could be funded through the Carl Moyer Program fund are determined as follows:

Incremental Capital Cost:	$ 9,500 - $ 6,900 = $ 2,600
Max. Amount funded from Carl Moyer Program:	$ 2,600
Capital Recovery:	$[(1 + 0.05)^5 (0.05)]/[(1 + 0.05)^5 – 1] = 0.23$
Annualized cost:	(0.23)($ 2,600) = $ 598/year
Cost-Effectiveness:	($ 598/year)/(0.38 tons/year) **= $ 1,574/ton**

The project meets the cost-effectiveness limit of $13,000 per ton NOx reduced and would qualify to receive the entire incremental cost ($2,600).

E. Reporting and Monitoring

The district has the authority to conduct periodic checks or solicit operating records from the applicant that has received Carl Moyer funds for new engine purchases or for equipment repowering or engine retrofit projects. This is to ensure that the equipment is operated as stated in the program application. Off-road diesel equipment operators participating in the Carl Moyer Program are required to keep appropriate records during the life of the project funded. Records must contain, at a minimum, total hours operated or amount of fuel used, and maintenance and repair information. Records must be retained and updated throughout the project life and made available at the request of the district.

CHAPTER IV.

LOCOMOTIVES

This chapter presents the project criteria for locomotives under the Carl Moyer Program. It also contains a brief overview of the locomotive industry, emission inventory, current emission standards, available control technology, potential incentive projects eligible for funding, recommended emission reduction calculations, and estimated cost benefits.

A. Introduction

Over the years, the focus of reducing emissions has been from stationary sources and on-road vehicles (light-, medium-, and heavy-duty). Off-road sources, such as locomotives, also contribute to California's pollution problem but have not been regulated in California until recently, although locomotives have been subject to various locally enforced opacity limits. Federal law prohibits California from setting standards for new locomotives and new engines used in locomotives. Only the USEPA has the authority to regulate emissions from locomotives, and has, in fact, adopted standards that phase-in beginning in 2000.

Participating railroads proposed to USEPA and ARB the establishment of a locomotive fleet average emissions program in the South Coast nonattainment area tied to promulgation of a USEPA National Locomotive Rule. ARB, USEPA and participating railroads committed to develop this program, known as the South Coast Locomotives Program, by signing a Statement of Principles (SOP) in May 1997. Following the signing of the SOP, the railroads, USEPA, and ARB discussed improvements and refinements of this program. In July 1998, a second agreement was signed that affects the in-use locomotive fleet in the South Coast nonattainment area. That agreement is a Memorandum of Understanding (MOU) signed by the ARB and participating railroads, agreeing to a voluntary locomotive fleet average emissions program that will speed the introduction of new, lower-emitting engines in the South Coast Air Basin.

1. Emissions Inventory

The primary business of railroads is transportation of freight or passengers. Locomotives provide line-haul, local (short-line), switchyard, and passenger services. In California, line-haul transportation is the primary function of the Union Pacific Railroad Company, and the Burlington Northern and Santa Fe Railway Company. These companies transport goods between major urban centers, sometimes over 1,000 miles apart. Reliability is an important factor when transporting goods at large distances. Locomotive "down-times" could be very expensive and are the cause of a tremendous loss in revenue. Hence, line-hauls are well maintained, with remanufacture occurring every seven to eight years.

Locomotives are well maintained and typically have a long useful life. Line-hauls with engines over 3000 horsepower (hp) and no longer suitable for line-haul service are typically designated for other services out of California, or even out of the U.S. Line-hauls less than 3000 hp that are no longer suitable for line-haul services, are usually re-assigned to the short-line fleets, and subsequently to the switchyards. Short-lines have smaller engines than line hauls since these locomotives require less work, carry smaller loads, and travel shorter distances, generally under 200 miles. Short-lines consist of an older locomotive fleet, mostly predating the 1973 model year. Switch-yard locomotives are usually the oldest locomotives, and require the least amount of travel and work. Switchers typically distribute and re-arrange cars within the terminal and provide services within the state, usually remaining in the same geographical area.

There are approximately 20,000 locomotives in the U.S and about 1,200 (or six percent) are in California. Of these 1,200 locomotives, approximately 250 are used as locals, 200 are used in switchyards, 100 are passenger trains, and the remaining 650 are used as line-hauls.[1] Locomotives generated approximately 3 to 4 percent of the 1990 baseline NOx emissions in the South Coast Air Basin.[2] Table IV-1 lists baseline NOx emissions for 1990, 1996, and 2010. The baseline NOx emissions listed in Table IV-1 do not reflect USEPA nationwide emission standards for new and remanufactured locomotives, or the MOU for the in-use locomotive fleet in the South Coast nonattainment area.

Table IV-1
Baseline NOx Emissions [a]
(tons/day)

Area	1990	1996	2010
South Coast	30	28	26
Statewide	160	150	140

a) Emission estimates from the ARB's emission inventory.

2. Emission Standards

USEPA adopted emission standards for locomotives nationwide in December 1997. The standards take effect in the year 2000. Federal standards apply to locomotives originally manufactured from 1973 and any time they are manufactured or remanufactured. Electric locomotives, historic steam-powered locomotives, and locomotives originally manufactured before 1973 are not regulated. Table IV-2 contains the federal exhaust emission standards for locomotives. Emission standards for short-line and line-hauls are both based on the line-haul duty cycle.

Table IV-2
Federal Exhaust Emission Standards for Locomotives
Beginning in 2000 for New Engines and at Time of Remanufacture

Duty-cycle	Gaseous and Particulate Emissions (g/bhp-hr)			
	HC	CO	NOx	PM
	Tier 0 (1973 – 2001 model years)			
Line-haul duty-cycle	1.00	5.0	9.5	0.60
Switch duty-cycle	2.10	8.0	14.0	0.72
	Tier 1 (2002 – 2004 model years)			
Line-haul duty-cycle	0.55	2.2	7.4	0.45
Switch duty-cycle	1.20	2.5	11.0	0.54
	Tier 2 (2005 and later model years)			
Line-haul duty- cycle	0.30	1.5	5.5	0.20
Switch duty-cycle	0.60	2.4	8.1	0.24

USEPA, Final Emissions Standards for Locomotives, EPA420-F-97-048, December 1997

3. Control Technology

Although locomotives and their engines are expensive, they are designed to last a long time. Typical lifetimes are between 25 and 30 years. Over this life, they are overhauled several times and, perhaps, re-engined once. For the most part, locomotive engines are well maintained and the emissions associated with these engines typically remain the same over their lifetime.

The desire to improve fuel economy has influenced the development of more advanced locomotive technologies. Locomotive exhaust emission levels have generally been reduced with the development of new engine technologies. These technologies are somewhat similar to those for on-road heavy-duty vehicle control technology. Technologies include, but are not limited to, turbocharging and aftercooling for NOx control, and improved fuel injection and combustion chamber design for PM and HC control.

B. Project Criteria

The project criteria for locomotives under the Carl Moyer Program have been designed to provide districts with a list of minimum qualifications that must be met by applicants in order for a reduced-NOx locomotive project to qualify for funding. These criteria will provide districts and program operators with calculations that must be used for determining emission reductions and cost effectiveness resulting from reduced-NOx locomotive projects. Reduced-NOx locomotive engine projects that include new, repowered, or retrofitted locomotive engines will be considered and closely evaluated as qualifying for incentive funding. For the most part the criteria for selecting a project will depend on the amount of emission reductions, cost effectiveness, and the potential for the project to materialize within a realistic timeframe. New criteria have been added in order to normalize the selected project life of a locomotive project. In general, locomotive projects that meet the following criteria would qualify for funding.

- Any emission reductions achieved through the application of Carl Moyer Program funds cannot be credited toward compliance with the 1998 MOU in the South Coast;

- NOx reductions for all other districts must be beyond what is required by any federal, local regulations, or other legally binding document;

- Engines must be tested according to the most current USEPA test procedures for Locomotives.

- Pre-1973 model year (MY) locomotives – must test to 15 percent below uncontrolled baseline NOx emissions;

- 1973 and later MY locomotives – must test to Tier 1 or Tier 2 federal locomotive NOx standards;

- The acceptable maximum project life for calculating project benefits are as follows:

	Default without Documentation	Default with Documentation
A new locomotive project	20 years	30 years
A repower or retrofit project	20 years	30 years

  A different project life may be selected for approval by ARB staff. However sufficient documentation must be provided to ARB that supports the selected project life based on the actual remaining useful life.

- Reduced emission levels must be maintained for a minimum of 5 years;

- Seventy-five percent of estimated annual ton-miles traveled must occur in California;

- Seventy-five percent of estimated annual fuel consumption must occur in California; and

- Cost effectiveness must be no more than $13,000 per ton of NOx reduced.

C. Potential Types of Projects

Typical projects that would qualify for incentive funding under this program would include repowering a locomotive engine to a reduced-NOx configuration, use of a retrofit kit to lower engine NOx emissions, or the purchase of new, reduced-NOx engines. Repowering and retrofit projects are not limited, and could include use of control technologies that involve selective catalytic reduction (SCR), dual-fuel natural gas engine retrofits, or even turbocharging and aftercooling. There are also reduced-emission technologies (such as engine retrofit or new engine technologies) that hold promise for the future, but are not yet commercially available or certified for sale in California. ARB could approve test data for these technologies on a case-by-case basis. Beginning in the year 2000, when the federal standards go into effect, ARB could grant an experimental permit for a particular engine with certain technology to operate in California. However, all projects will be evaluated carefully to determine whether or not NOx reductions could indeed occur.

Reliability of a line-haul engine is extremely important. Since some of the control technologies are costly and have not been in wide use for locomotive engines, line-haul participation in the Carl Moyer Program is not expected until these technologies are proven effective and reliable on passenger, short-line, and switcher locomotive engines. Therefore, the ARB expects that reduced-NOx locomotive projects would be limited to passenger, short-line, or switchyard locomotives.

1. Repowers

Repowering could occur during engine remanufacture by exchanging a locomotive's old engine for a newer, lower-emission engine. According to these criteria the amount of funding granted and final project qualifications must be based on the amount of emissions reduced and a cost effectiveness of at most $13,000 per ton. There is no cap on the amount of funding received. However, in order to qualify for funding, locomotive engines must test to a reduced-NOx emissions level according to USEPA test procedures for locomotives. The reduced-NOx emission level must be maintained for a minimum of 5 years (project life).

Projects submitted for pre-1973 MY locomotives must show that engine NOx emissions will be reduced by a minimum of 15 percent below the uncontrolled baseline NOx emissions for pre-1973 MY, as listed in Table IV-3, below. Since there are no line haul locomotives in service in California with pre-1973 engines, these projects are likely to be for switchers. Projects submitted for 1973 and later MY locomotive engines must consist of engines tested to the federal Tier 1 or Tier 2 locomotive NOx standards as listed in Table IV-3, below. Engine tests must be conducted according to the Federal Test Procedures for locomotives. If additional funding is available beyond the calendar year 2001 to continue the Carl Moyer Program, criteria for project NOx limits will be modified to reflect the current federal standards.

Table IV-3 Baseline NOx Emission Factors and Maximum NOx Limits (g/bhp-hr)			
Engine Model Year	**Source**	**Line-haul**	**Switcher**
Pre-1973	Uncontrolled Baseline Emission Factor	16 [a, b]	16.9 [b]
1973 and later	Baseline Emission Factor	9.5	14.0
1973 and Later	NOx Limit – Federal Tier 1	7.4	11.0
	NOx Limit – Federal Tier 2	5.5	8.1

a. There are no line haul locomotives in service in California that are pre-1973, baseline emissions are listed for short-line locomotives only.
b. ARB emission rates are average estimates based on data provided by engine manufacturers.

2. Retrofits

Retrofit involves hardware modifications to the engine, so the engine has lower emissions. The conversion could occur by adding on control equipment to convert the engine to a reduced-NOx engine technology. This technology could include conversion to an alternative fuel locomotive engine. The amount of funding granted and the final project qualifications must be based on the amount of emissions reduced and a cost effectiveness of at most $13,000 per ton. Similar to repowers, in order to qualify for funding, locomotive engines must test to a reduced-NOx emissions level according to USEPA test procedures for locomotives. As with repowers, the tested emission level must be maintained for a minimum of 5 years (project life).

The maximum allowable NOx levels for line-haul and switchers using retrofit kits will be the same as for repowers. Projects submitted for pre-1973 MY locomotives must show that engine NOx emissions will be reduced by a minimum of 15 percent below the uncontrolled baseline NOx emissions as listed in Table IV-3, above. Projects submitted for 1973 and later MY locomotive engines must consist of engines tested to the federal Tier 1 or Tier 2 locomotive NOx standards as listed in Table IV-3, above. Once again, if additional funding is available beyond the calendar year 2001 to continue the Carl Moyer Program, criteria for project NOx limits will be modified to reflect the current federal standards.

3. Sample Project Application Forms

In order to qualify for incentive funds, districts will make applications available and solicit bids for reduced-emission projects from railroads. A sample application has been provided in Appendix E. The applicant must provide at least the following information, as listed in Table IV-4 below:

Table IV-4 Minimum Application Information Locomotive Projects	
1. Air District: 2. Applicant Demographics Company Name: Business Type: Mailing Address: Location Address: Contact Number: 3. Project Description Project Name: Locomotive Type: Engine Type: Vehicle Class: 4. Annual Ton-Miles: 5. Project Life (years): 6. Old Engine Information Horsepower Rating: Engine Make: Engine Model: Engine Year: 7. New Engine Information Horsepower Rating: Engine Make: Engine Model: Engine Year: Fuel Type:	8. NOx Reduction Incremental Cost Effectiveness Analysis Basis: (Mileage/Fuel/Hours of Operation) 9. VIN or Serial Number: 10. Application: (Repower, Retrofit or New) 11. Percent Operated in California: 12. Percent Operated in Air District: 13. Annual Diesel Gallons Used: 14. Fuel Consumption Rate: 15. NOx Emissions Reductions Baseline NOx Emissions Factor (g/bhp-hr): NOx Conversion Factors Used: Reduced NOx Emissions Factor (g/bhp-hr): Estimated Annual NOx Emissions Reductions: Estimated Lifetime NOx Emissions Reductions: 16. Cost ($) of the Base Engine: 17. Cost ($) of Certified LEV Engine: 18. PM Emissions Reductions Baseline PM Emissions Factor (g/bhp-hr): PM Conversion Factors Used: Reduced PM Emissions Factor (g/bhp-hr): Estimated Annual PM Emissions Reductions: Estimated Lifetime PM Emissions Reductions: 19. District Incentive Grant Requested:

D. Emission Reduction and Cost-Effectiveness

Control costs for locomotives differ greatly, depending on the particular scenarios and technology involved in any individual case. Preliminary cost evaluations of some reduced-NOx controls for locomotive engines indicate that the capital costs can be high (although less than purchasing a new engine), whereas some cost evaluations indicate that others could actually create a cost savings to locomotives. The amount of incentive funds granted depends on the amount of emission reductions. Only the portion of the incremental cost that meets a cost effectiveness of at most $13,000 per ton of NOx reduced will qualify for incentive funding.

1. Emission Reduction Calculation

Emission reductions for locomotives will be based on annual fuel consumption or hours of operation, and percent operated in California. If the applicant provides annual hours of operation, a fuel consumption rate must also be provided. Annual emissions must be estimated for the baseline engine and the new engine separately, taking into consideration baseline activity levels as compared with future activity levels. Annual emissions for each engine are calculated by multiplying the NOx emission factor by the energy consumption factor of 20.8 bhp-hr/gal, and the estimated annual fuel consumption. The results for both engines are subtracted, multiplied by the percent operated in California, then converted to tons.[3] If annual hours of operation are provided, the annual fuel consumption is calculated by multiplying the fuel consumption rate by the annual hours of operation. The following formulas must be used when calculating project NOx reductions.

Annual NOx Reductions (tons/year) =
[(Ann. Fuel Cons. * Fuel Cons. Factor * Baseline NOx Emissions) –
(Ann. Fuel Cons. * Fuel Cons. Factor * Reduced NOx Emissions)] *
% operated in CA * ton / 907,200 grams

Where,

Ann. Fuel Cons	= Estimated Annual Fuel consumption for the retrofitted engine(gal/year). If not known, provide annual hours of operation and a fuel consumption rate.
Fuel Cons. Factor	= Assumed Fuel Consumption Factor of 20.8 bhp-hr/gal
Baseline NOx Emissions	= NOx Emission factor from the old engine in g/bhp-hr
Reduced NOx Emissions	= NOx Emission factor from the new engine in g/bhp-hr
% operated in CA	**=** The percent of time operated in California
(ton/907,200 g)	Converts grams to tons

2. Cost Effectiveness Calculation

The cost-effectiveness is based on the incremental capital cost, any matching funds that were used to fund the project, the expected life of the project, the interest rate (five percent), and estimated annual NOx reductions in a particular district. The discount rate of five percent reflects the opportunity cost of public funds for the Carl Moyer Program. This is the level of earning that could be reasonably expected by investing state funds and is based on the most recent published interest rates on U.S. Treasury securities.

Incremental costs are determined by considering the difference between the capital cost to remanufacture an engine to its original configuration (without improved control technology) and the capital cost to repower/retrofit the engine with new control technology. The incremental capital cost is annualized using a five percent interest rate. Incremental costs are multiplied by a capital recovery factor, and divided by the annual NOx reductions in a district. This calculation will result in annualized project cost-effectiveness. Larger NOx reductions could result in better cost-effectiveness, depending on the amount of project incremental cost. Cost-effectiveness can be calculated using the following formulas:

Incremental Project Cost = (Aft. Proj. Cap. Cost) - (Bef. Proj. Cap. Cost)

Where,

Aft. Proj. Cap. Cost = capital costs for reduced-NOx engine
Bef. Proj. Cap. Cost = capital costs for the rebuilt engine without the upgrade

Maximum Amount Funded = (Incremental Project Cost) - (Match Funds)

Where,

Match Funds = Any matching funds

Capital Recovery Factor = $[(1 + i)^n (i)] / [(1 + i)^n - 1]$

Where,

i = discount rate (5 percent)
n = project life (at least five years)

Annualized Cost = [(Maximum Amount) + (Match Funds)] * (Capital Recovery Factor)

Cost-Effectiveness = (Annualized Cost) / (Annual NOx Reductions)

Where,

Annual NOx Reductions = Calculated NOx reductions (tons/year)

3. Examples

For the purposes of explaining the emission reduction and the cost effectiveness calculations from a locomotive engine project, two examples are presented below. The first example describes the calculations based on fuel consumption, whereas the second example provides an explanation for the calculations based on hours of operation.

Example 1 – Locomotive Engine Retrofit: Consider an operator faced with the opportunity to convert one locomotive engine, perhaps during the normal remanufacture period. In this case, the railroad applies for funding for a locomotive compressed natural gas retrofit kit for a 1972 short-line engine. The retrofit kit reduces uncontrolled emissions by 30 percent. Since it is usually about seven years until the next remanufacture, the project life is seven years. The railroad company estimates the remanufacture of the engine without the retrofit kit to be about $890,000. The upgrade, however, is more expensive, and will cost a total of $920,000. The railroad also estimates that the annual fuel consumption for this engine in California would be approximately 60,000 gals. Emission reductions are calculated using the formula listed in section D1, above, as follows:

Annual Fuel Consumption:	60,000 gals/year
Baseline NOx Emissions:	16.0 g/bhp-hr
Reduced NOx Emissions:	11.2 g/bhp-hr (30 percent reduction from 16.0 g/bhp-hr)
Fuel Cons. Factor:	20.8 bhp-hr/gal
% operated in CA:	100%
(ton/907,200 grams):	converts grams to tons

Estimated annual NOx reductions are:

[(60,000gal/year * 20.8 bhp-hr/gal * 16 g/bhp-hr) – (60,000 gal/year * 20.8 bhp-hr/gal 11.2 g/bhp-hr)] * 1 * ton / 907,200 g) = **6.6 tons/year**

Using the formulas in section D2, above, and the cost assumptions provided earlier in this section, the capital costs, the incremental costs and benefits can be calculated as follows:

Capital Costs for remanufacture without Upgrade	$ 890,000
Capital costs for remanufacture with retrofit kit	$ 920,000
District Matching funds	$ 0

Incremental Project Cost:	($ 920,000 - $ 890,000) = $ 30,000
Maximum Amount Funded:	($ 30,000 - $ 0) = $ 30,000
Capital Recovery Factor:	$[(1 + 0.05)^7 (0.05)]/[(1 + 0.05)^7 – 1] = 0.17$
Annualized Cost:	($ 30,000 + $ 0) * (0.17) = $ 5,100/ year
Cost Effectiveness:	($ 5,100 / year) / (6.6 tons/year) = **$ 773/ ton**

The cost effectiveness for the example is less than $13,000 per ton of NOx reduced. This project would qualify for the maximum amount of grant funds.

Example 2 – Locomotive Engine Replacement: Consider an operator faced with the opportunity to replace a short-line locomotive engine, perhaps during the normal remanufacture period. In this case, the railroad applies for funding for a short-line locomotive to replace a 1983 short-line engine (9.5 g/bhp-hr NOx) with a liquefied natural gas (LNG) engine (4.0 g/bhp-hr NOx). The railroad company estimates a project life of 20 years for the LNG engine. The railroad company also estimates the normal remanufacture costs for the engine to be about $890,000. The LNG upgrade, however, is more expensive, and will cost a total of $1.2 million. The railroad also estimates that the annual hours of operation for the new engine to be 1000 hours per year, with an average fuel consumption rate of 260 diesel equivalent gallons per hour. Emission reductions are calculated using the formula listed in section D1, above, as follows:

Annual Fuel Consumption:	1000 hrs/yr * 260 gals/hr = 260,000 gals
Baseline NOx Emissions:	9.5 g/bhp-hr
Reduced NOx Emissions:	4.0 g/bhp-hr

Energy Consumption Factor:	20.8 bhp-hr/gal
% operated in CA:	100%
(ton/907,200 grams):	converts grams to tons

Estimated annual NOx reductions are:
[(260,000 gal/year * 20.8 bhp-hr/gal * 9.5 g/bhp-hr) - (436,800 gal/year * 20.8 bhp-hr/gal * 4.0 g/bhp-hr)] * 1 * ton / 907,200 g = **16.6 tons/year**

Using the formulas in section D2, above, and the cost assumptions provided earlier in this section, the capital costs, the incremental costs and benefits can be calculated as follows:

Capital Costs for remanufacture without Upgrade	$ 890,000
Capital costs for LNG engine	$1,200,000
Matching funds	$ 0

Incremental Project Cost:	**$** 1,200,000 - $ 890,000 = $ 310,000
Maximum Amount Funded:	**$** 310,000 – $ 0 = $ 310,000
Capital Recovery Factor:	$[(1 + 0.05)^{20} (0.05)]/[(1 + 0.05)^{20} – 1] = 0.08$
Annualized Cost:	($ 310,000 + $ 0) * (0.08) = $ 24,875/ year
Cost Effectiveness:	($ 24,875 / year) / (16.6 tons/year) = **$ 1,498/ ton**

The cost effectiveness for the example is less than $13,000 per ton of NOx reduced. This project would qualify for the maximum amount of grant funds ($310,000).

E. Reporting and Monitoring

The district has the authority to conduct periodic checks or solicit operating records from the applicant that has received Moyer funds for each retrofitted/repowered locomotive engine. This is to ensure that the engine is operated as stated in the program application. The applicant must maintain operating records and have them available to the district upon request. Records must contain, at minimum, locomotive identification numbers, retrofit hardware model and serial numbers, estimated annual fuel consumption in the California, hours of operation in California, hours in idle, and maintenance/repair dates (or any type of servicing information), and any emission testing results. Records must be retained and updated throughout the project life and made available for district inspection.

F. References

1. Controlling Locomotive Emission in California: Technology, Cost-Effectiveness, and Regulatory Strategy, Chris Weaver and Douglas McGregor, Engine, Fuel, and Emissions Engineering, Inc., March 1995.

2. Locomotive Emission Study California Air Resources Board, Booz, Allen, & Hamilton, January 1991.

3. Emission Factors for Locomotives, USEPA, EPA420-F-97-051, December 1997.

CHAPTER V.

MARINE VESSELS

This chapter presents the project criteria for marine vessels under the Carl Moyer Program. It also contains a brief overview of the marine vessel industry, NOx emission inventory based on emissions calculated for the South Coast Air Basin, current emission standards, available control technology, potential incentive projects eligible for funding, recommended emission reduction calculations, and estimated cost benefits.

A. Introduction

Marine vessel engines contribute to emissions of NOx, HC, CO, PM, and SOx. Marine vessel traffic consists of foreign and domestic (U.S. based) fleets. Emissions from marine vessel engines are generated in California during vessel travel through defined California coastal waters, vessel calls on California ports, as well as from other vessel activities in and near the ports such as fishing, tugboat operations and work boats. The coastal water boundary for California consists of a range from 27 miles off of the California coast at the narrowest, to 102 miles off the coast at the widest (Figure V-1 shows this boundary). There have been recent actions on both the international and national level to address the emissions from marine vessel engines. While some strategies being discussed for the South Coast Air Basin may generate emission reductions in the near-term, the full effects from the international and national emission control programs won't be realized for many years since these regulations apply, with certain exceptions, to new engines.

The Carl Moyer Program presents a timely opportunity to realize emission reductions from marine vessels within the next 2-5 years. By providing marine vessel owners with incentive funds for voluntarily reducing NOx emissions from marine vessel engines before mandated regulatory controls are effective, this program has the potential to generate near-term emission reductions from the marine fleet. These emission reductions, in turn, will benefit the local air quality districts' efforts to meet the health based air quality standards.

1. Emission Inventory

The marine vessel source category includes ocean-going vessels and harbor vessels exclusive of those used in recreational activities. Marine vessel fleets range in power, from approximately 500 to 67,000 horsepower. Marine vessels, for the most part, are propelled by diesel engines and to a smaller extent by steam turbines, or gas turbines. In 1993, approximately 95 percent of the vessels calling on the San Pedro Bay Ports were propelled by diesel engines, with the remaining 5 percent propelled by steam turbines. Typical lifetime for a marine vessel engine is approximately 30 years, with rebuilds occurring about every five years.

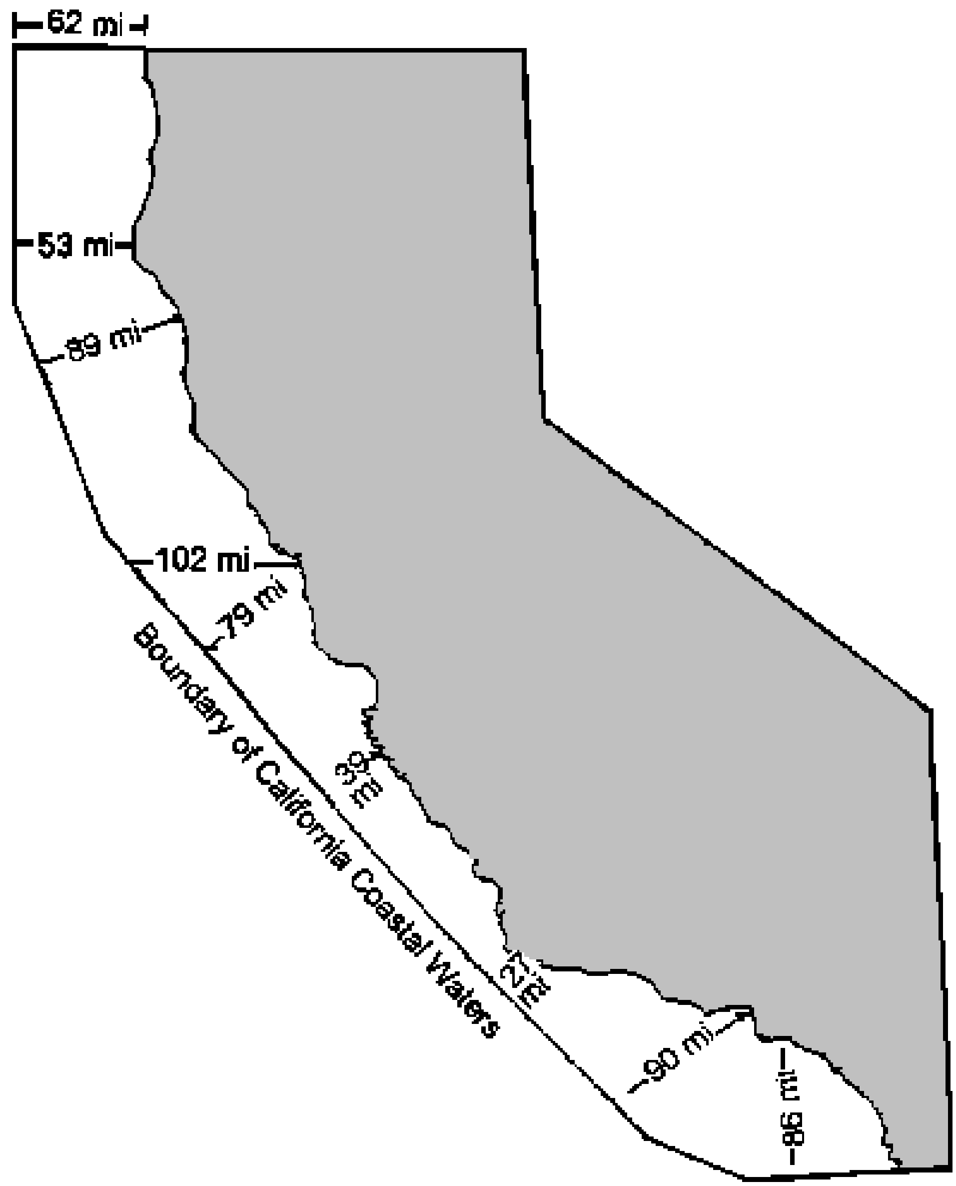

Figure V-1 Coastal water boundaries from the California Air Resources Board's *Report to the California Legislature on Air Pollutant Emissions from Marine Vessels, 1984*

The emission inventory for the South Coast Air Basin shows significant NOx emissions from ocean-going vessels, tug boats, harbor vessels, fishing vessels, U.S. Navy and Coast Guard, and transiting vessels. In 1993 approximately 1,500 vessels made 5,500 calls on the San Pedro Bay Ports in the South Coast. Approximately 94 percent of the 1,500 vessels were foreign and six percent were U.S. vessels. Estimated emissions from these engines are calculated for both the main engines and the auxiliary power engines operating in either or all of the following modes:

- Cruising,
- Maneuvering, and
- Hotelling

Baseline NOx emissions for 1990 are estimated to be approximately 32 tons per day in the South Coast Air Basin (SCAB). In 2010, NOx emissions are expected to be approximately 52 tons per day in the SCAB which is approximately eight percent of total mobile source NOx emissions for that year. Table V-1 lists 1990, 1996, and 2010 estimated NOx emissions from marine vessel engines in the South Coast and statewide**.**

Table V-1
Baseline NOx Emissions
(tons/day)

Area	1990	1996	2010
South Coast	32	41	52
Statewide	58	66	79

Emission estimates from the ARB's emission inventory.

2. Emission Standards

At the international level, the International Maritime Organization (IMO) adopted Annex VI to the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78). This protocol, which is expected to be signed by more than 15 countries representing over 50 percent of the commercial tonnage worldwide, will reduce NOx emissions from new engines installed on ships after January 1, 2000. MARPOL 73/78 prevents USEPA from setting lower emission standards for engines on marine vessels traveling to or from foreign countries. USEPA has the authority to propose marine vessel standards for domestic vessels that remain in national waters. As such, USEPA adopted marine standards in December 1999 for domestic vessels not subject to IMO standards. Table V-2 lists the IMO standards for NOx emissions.

Table V-2
IMO NOx Standards
Effective January 1, 2000

Engine Speed, n	NOx (g/kW-hr)	NOx (g/bhp-hr)
N < 130	17	12.7
1 130 < n < 2000	$45 * n^{-0.2}$ = 17.0 at 130 rpm and 9.8 at 1999 rpm	= 12.7 at 130 rpm and 7.3 at 1999 rpm
n = 2000 +	9.8	7.3

Source: USEPA, 40 CFR Part 89, Control of Emissions of Air Pollution from New CI Marine Engines at or above 37 Kilowatts, May 11, 1998.

At the national level, the USEPA adopted regulations in December 1999 to limit the emissions from domestic vessels not subject to the IMO standards. The adopted federal marine standards sets challenging emission standards for marine diesel engines that are similar to land-based nonroad or locomotive engine (with displacement up to 30 liters per cylinder). These USEPA adopted NOx standards take effect starting between 2004 and 2007, depending on the size of the engine, and supersede the requirements by the IMO. As a new approach, engine manufacturers need to demonstrate compliance with the emission standards over a variety of operating conditions. These "off-cycle" requirements become effective with the new emission standards. In addition, the USEPA has been exploring potential control options for reducing the emissions from marine vessels in the South Coast Air Basin to fulfill USEPA's obligation for Measure 13 (M-13) in the 1994 Ozone State Implementation Plan. These discussions have focused on a wide variety of emission reduction strategies including operational controls in the basin such as voluntary speed reduction and moving of the shipping channels as well as port infrastructure improvements and strategies to retrofit engines on harbor vessels. Table V- 3 lists the USEPA standards for NOx emissions.

Table V-3
USEPA NOx Standards

Displacement (liters/cylinder)	Starting Date	NOx (g/kW-hr)	NOx (g/bhp-hr)
Power ∃ 37 kW Displacement <0.9	2005	7.3	5.4
0.9 # Displacement < 2.5	2004	7.0	5.2
2.5 # Displacement <5.0	2007	7.0	5.2
5.0 # Displacement <15	2007	7.7	5.7
15 # Displacement <20 Power <3300 kW	2007	8.6	6.4
15 # Displacement < 20 Power ∃ 3300 kW	2007	9.6	7.2
20 # Displacement < 25	2007	9.6	7.2
25 # Displacement < 30	2007	10.8	8.1

Source: USEPA, 40 CFR Part 89, Control of Emissions of Air Pollution from New CI Marine Engines at or above 37 Kilowatts, December 29, 1999.

3. Control Technology

Marine vessel engines in tugboats and fishing vessels are very similar to locomotive and heavy-duty truck-type engines. Marine vessel engines are costly and designed to last a long time. Typical lifetime is about 30 years. Over this period, engines are overhauled at regular five-year intervals. Since they are often overhauled regularly, applying control technologies at the point of overhaul would be the least disruptive and least costly approach. The technology required to meet lower NOx emissions are somewhat similar to those for on-road heavy-duty vehicle and locomotive control technology. Technologies include exhaust after-treatment, and advanced technologies that have been applied to on-road engines. Dual-fuel natural gas retrofit kits are available that could lower NOx emissions from marine vessel engines (fishing boats) by about 30 to 40 percent. Selective catalytic reduction (SCR) which is used for land based applications, could also be used on vessels. There are about eight marine vessels operating with SCR.

B. Project Criteria

The project criteria for marine vessels under the Carl Moyer Program are designed to provide districts with a method for evaluating reduced-NOx marine vessel projects that are submitted to them for receiving incentive funding. Reduced-NOx marine vessel engine projects that include new, repowered, or retrofitted engines will be considered and evaluated for incentive funding. For the most part the criteria for selecting a project depends on the amount of emission reductions, cost effectiveness, and the potential for the project to materialize within a realistic timeframe. These criteria also provide districts and program operators with calculations that must be used for determining emission reductions and cost effectiveness resulting from reduced-NOx marine vessel projects.

The project criteria have been revised to include two new criteria. 1) a maximum allowable project life in order to normalize the project life selected for a marine vessel project; and 2) a boundary where emission benefits would be determined for marine vessel projects funded under the Carl Moyer Program. Marine vessel projects qualifying for evaluation would need to meet the following criteria:

- At minimum 15 percent reduction in NOx emissions from uncontrolled baseline emissions for repowers and at minimum 30 percent reduction for new purchases

- Emission reductions must be beyond what is required by any, national or international regulations;

- NOx emissions must be validated according to USEPA test procedure ISO8178-4:1996(E), 8.5, Test Cycle Type E – Marine Applications.

- When the horsepower rating of the new engine differs from that of the existing engine by 25 percent, the difference in the rating must be taken into account in the emission reduction calculation by multiplying the estimated emissions from the new engine using the following factor:

$$\text{Modified Emissions} = E_{new} * \frac{\text{Rating of new engine}}{\text{Rating of old engine}}$$

  where, E_{new} = the emissions from the new engine

- Reduced emission levels must be maintained for a minimum of 5 years; and

- Cost effectiveness no more than $13,000 per ton of NOx reduced in California Coastal waters.

- The acceptable project life for calculating project benefits from marine vessels are as follows:

	Default without Documentation	Default with Documentation
Fishing/Other Small Vessels –	10 years	20 years
Ferries/Tugs/Large Vessels –	20 years	30 years

  A different project life may be selected for approval by ARB staff. However sufficient documentation must be provided to ARB that supports the selected project life based on the actual remaining useful life.

- Associated project benefits calculated for marine vessels funded under the Carl Moyer Program must be based on the amount of time a marine vessel operates within the district's emission inventory boundary (distance away from shore). If a local district has not established an emission inventory boundary, ARB staff has set a default value of 10 miles off shore.

C. Potential Types of Projects

Since many ocean-going vessels do not call on ports frequently during the year, controls may not be as cost effective for these vessels. For the most part, cost effective projects will be those that include controls incorporated on vessels that frequent the ports or remain in the harbor. These types of vessels include, but are not limited to, tugs, crew/supply boats, and fishing boats. Typical projects that would qualify for incentive funding under the Carl Moyer Program for marine vessels would include the use of retrofit kits or repowers to lower NOx emissions, the purchase of new reduced-NOx marine engines, or the purchase of reduced-NOx portside equipment. However, projects where gasoline (i.e., natural gas or gas) engines are replaced with new diesel engines or diesel engines are replaced with gasoline engines (excluding natural gas) are not eligible for Carl Moyer Program funds.

Projects consisting of new marine vessel engines that produce reduced-NOx emissions would also be considered for funding. However, incremental costs for new engines may be too high to qualify this type of project as cost effective.

Projects consisting of reduced-NOx portside equipment could also be considered for incentive funds. These types of projects would be less costly, compared to marine engine control. However, NOx emission reductions and cost effectiveness would depend on the amount of operation hours from these types of equipment. The types of equipment, as well as the extent of operation, could vary considerably in each port. Hence, these types of projects would need to be evaluated individually to determine the project eligibility.

1. Repowers & Retrofits

Repowering could occur during engine rebuild by exchanging a marine vessel's old engine for a newer, lower-emission engine. Retrofit involves hardware modifications to the engine, so the modified engine emits lower emissions. The conversion could occur by adding on control equipment to convert the engine to a reduced-NOx engine technology. In both cases, funding eligibility will be evaluated based on the amount of emissions reduced and a maximum cost effectiveness of $13,000 per ton. Furthermore, the cleaner engine would need to test to an emission limit that is at least 15 percent lower then uncontrolled baseline NOx emissions. If a baseline emission limit is not provided by the applicant, an average baseline uncontrolled emission factor will be used when calculating emissions. These factors were provided to ARB by the SCAQMD and are listed in Tables V-4 through V-7. The emission level will have to be maintained for the project life.

The emission factors listed in Table V-4 apply to engines in the original engine manufacturer (OEM) configuration. If the engine has been modified to produce lower NOx emissions for any reason, these factors are not applicable. For engines modified from the OEM configuration, baseline emission factors must be based on in-situ source test data. In lieu of using the emission factors listed in Table V-4, baseline emissions may still be determined by using ARB approved in-situ source testing. If source testing is performed, test results must be used even if testing indicates lower or higher emission factors than the default factors listed. The maximum acceptable value of a baseline emission factor derived from in-situ source testing is 20 g/bhp-hr.

Table V-4
Harbor Vessel Emission Factors – Medium Speed Diesels
(g/bhp-hr)

Emissions Configuration	2 Stroke[a] Naturally-Aspirated (g/bhp-hr)	2 Stroke[a] Turbocharged (g/bhp-hr)	4 Stroke[b] Naturally-Aspirated (g/bhp-hr)	4 Stroke Turbocharged[b], Turbocharged/ Aftercooled (g/bhp-hr)
Uncontrolled (Pre 1980)	14[c]	11	8	7
Off-highway 1980+ (Pre-EFI)[d]	8	7	7	6

Notes:
a. 2 Stroke = Typically DDC-53 or –71 series
b. 4 Stroke = Cat/Cummins and others
c. The 14 g/bhp-hr baseline is listed for EMD engines used in marine applications
d. EFI = Electronic Fuel Injection

Table V-5
Marine Vessel Emission Factors for all Design Categories
(lbs/1000 gal)

Propulsion Type	Speed	Cruise Baseline NOx	Maneuvering Baseline NOx
Motorship	Slow Speed (2 Stroke)	616	616
	Medium Speed (4 Stroke)	403	403
Steamship		64	56

Table V-6 Marine Vessel Auxiliary Power Emission Factors for all Design Categories (lbs/hour)			
Vessel Type	**Propulsion Type**	**Auxiliary Power**	**Baseline NOx**
All	Motorship	Engines	22
		Boilers	4
	Steamship	Main Boilers	29

Table V-7 U. S. Navy Ship Emission Factors (lbs/1000 gal)	
Vessel Type	**Baseline NOx**
Motorship	652
Steamship	64

2. Portside Equipment Repowers & Retrofits

Projects that consist of portside equipment engine repowers and retrofits could also qualify for incentive funds. Similar to marine vessel engine repowers and retrofits, these projects will be evaluated based on the amount of emissions reduced and a cost effectiveness of at most $13,000 per ton. However, the cleaner engine would need to reduce NOx emissions to levels as described in the off-road equipment section of the Carl Moyer Program. In addition, the new certified emission level will have to be maintained for the project life.

3. Sample Project Application Forms

In order to qualify for incentive funds, districts provide project applications and solicit bids for reduced-emission projects from marine vessel owners. A sample application has been provided in Appendix F. The applicant must provide at least the following information, as listed in Table V-8.

Table V-8 Minimum Application Information Marine Vessel Projects	
1. Air District: 2. Applicant Demographics Company Name: Business Type: Mailing Address: Location Address: Contact Number: 3. Project Description Project Name: Vessel Type: (passenger ship, ferry, fishing boat, tug boat, etc.) Propulsion Type:(motorship or steamship) Engine Function: Ship Service Speed: Ship Deadweight Tonnage (DWT): 4. Avg. fuel consumption (gallons) per port call for each service mode Cruise: P-zone Cruise: Maneuvering: Hotelling: 5. Annual number of Port Calls in California: 6. Avg. time (hours) per port call in each service mode, and fuel consumption rate Cruise: P-zone Cruise: Maneuvering: Hotelling: 7. Ave. fuel consumption (gallons) per port call for Auxiliary Power a) Boilers (motorship) b) Engines (motorship) c) Main boilers (steamship) 8. Application: (Repower, Retrofit or New)	9. Percent Operated within districts emission inventory: 10. Project Life (years): 11. Average Nautical Miles per port call within California coastal water boundary: 12. Old Engine Information Horsepower Rating: Engine Make: Engine Model: Engine Year: 13. New Engine Information Horsepower Rating: Engine Make: Engine Model: Engine Year: Fuel Type: 14. NOX Emissions Reductions Baseline NOx Emissions Factor (g/bhp-hr): NOx Conversion Factors Used: Reduced NOx Emissions Factor (g/bhp-hr): Estimated Annual NOx Emissions Reductions: Estimated Lifetime NOx Emissions Reductions: 15. Cost ($) of the Base Engine 16. Cost ($) of Certified LEV Engine: 17. PM Emissions Reductions Baseline PM Emissions Factor (g/bhp-hr): PM Conversion Factors Used: Reduced PM Emissions Factor (g/bhp-hr): Estimated Annual PM Emissions Reductions: Estimated Lifetime PM Emissions Reductions: 18. District Incentive Grant Requested:

D. Emission Reductions and Cost-Effectiveness

1. Emission Reduction Calculation

Emission reductions for marine vessel engines are based on annual fuel consumption, and percent operated within a district's emission inventory boundary. The applicant must provide information pertaining to the amount of annual fuel consumed for the main engines, and the auxiliary power, depending on the vessel type. When calculating emission reductions, fuel consumption is multiplied by a specific NOx emission factor and then converted to tons per year. Emission factors for each engine are based on vessel type, propulsion type, and service mode. Average emission factors for uncontrolled baseline NOx emissions listed in Tables V-3 through V-6 above can be used where actual uncontrolled baseline emissions are not known.

Emission reductions for marine vessels could also be calculated based on hours of operation, as long as the applicant also provides the fuel consumption rate. When annual hours of operation are provided, the annual fuel consumption is estimated by multiplying the fuel consumption rate by the annual hours of operation. The estimated annual fuel consumption will then be used to determine NOx reductions. The following formulas must be used when calculating project NOx reductions.

Annual NOx Reductions (tons/year) =
[(Ann. Fuel Cons.) * [(Baseline NOx Emissions) - (Reduced NOx Emissions)] * (% operated in CA)] * (ton / 2,000 lbs)

where,

Annual Fuel Consumption	=	Estimated Annual Fuel consumption for the retrofitted/repowered engine(gal/year)
Baseline NOx Emissions	=	NOx Emissions from the overhauled engine (without retrofit/repower)
Reduced NOx Emissions	=	NOx Emissions from the new engine
% operated in CA	**=**	The percent of time operated in California
(ton/2,000 lbs)		Converts lbs/year to tons/year

There is a degree of uncertainty regarding the amount of offshore emissions that actually reach the mainland. The Southern California Ozone Study (the Tracer Dispersion Study) was conducted and completed by ARB to determine offshore impacts. Results from this study indicate that emission reductions from marine vessels would benefit ozone, PM, and toxic emissions that indeed reach the mainland. However, there is still uncertainty on the amount of emissions that actually reach the shore.

Each district establishes an emission inventory boundary that is used for determining pollutant sources, as well as the amount of emissions within a district. For districts located along the California Coast, that boundary may extend to the coastal water boundary, or at distances closer to the shoreline. Since districts have established inventory boundaries for claiming the amount of emissions within a district, that boundary will also be used to determine the range of offshore emissions that would be included in the emission benefits calculated for marine vessel projects. Hence, emissions for marine vessel projects would be calculated based on the amount of time a marine vessel operates within statewide coastal district emission inventory boundaries. If a local district has not established an emission inventory boundary, ARB staff has set a default value of 10 miles off shore.

2. Cost-Effectiveness Calculation

Typical marine vessel engine control projects, although technologically feasible, also have higher initial capital cost. Control technologies for a particular vessel will be associated with a certain annual cost each year, but emission reductions will vary from year to year depending on the amount of calls in a port. Emission reductions might even be zero in some years, making some control options less cost effective. Each application will be carefully evaluated on a case-by-case basis.

The cost –effectiveness is based on the incremental capital cost, any matching funds that were used to fund the project, the expected life of the project, the interest rate (five percent), and estimated annual NOx reductions. The discount rate of five percent reflects the opportunity cost of public funds for the Carl Moyer Program. This is the level of earning that could be reasonably expected by investing state funds and is based on the most recent interest rates published.

Incremental costs are determined by considering the difference between the capital cost for overhauling/rebuilding an engine to its original configuration (without improved control technology) and the capital cost to repower the engine or retrofit the engine with new control technology. Incremental costs are multiplied by a capital recovery factor and divided by the annual NOx reductions. This calculation will result in annualized project cost-effectiveness. Cost-effectiveness can be calculated using the following formulas:

Incremental Project Cost = (Aft. Proj. Cap. Cost) - (Bef. Proj. Cap. Cost)

Where, **Aft. Proj. Cap. Cost =** capital costs for reduced-NOx engine
Bef. Proj. Cap. Cost = capital costs for the rebuilt engine without the upgrade

Maximum Amount Funded = (Incremental Project Cost) - (Match Funds)

Where, **Match Funds =** Any matching funds

Capital Recovery Factor = $[(1 + i)^n (i)]/[(1 + i)^n - 1]$

Where, i **=** discount rate (5 percent)
n **=** project life

Annualized Cost = (Maximum Amount + Match Funds) * Capital Recovery Factor

Cost-Effectiveness = Annualized Cost / Annual NOx Reductions

Where, **Annual NOx Reductions =** Calculated NOx reductions (tons/year)

3. Examples

For the purposes of explaining the emission reduction and cost effectiveness calculations for a particular marine vessel project, two examples are presented below. These examples describe the calculations based on fuel consumption. If hours of operation and a fuel consumption rate are provided, the annual fuel consumption will be estimated and put into the calculation accordingly.

Example 1 – Tugboat Engine Repower: Consider an owner faced with the opportunity to replace one tugboat engine perhaps during the normal engine overhaul period. In this case, the marine owner applies for funding to repower one 1,400 hp tugboat engine with a low emission diesel engine. The repowered engine reduces uncontrolled NOx emissions by 40 percent, with a project life of about 20 years. The marine vessel owner estimates that the capital cost for rebuilding a 1,400 hp marine vessel engine without the upgrades is about $100,000. The upgrade, however, is more expensive, with a quoted price of $250,000. The marine vessel owner also estimates that the annual fuel consumption for this tugboat in California would be approximately 90,000 gallons.

<u>Emission Reduction Calculation</u>

Annual Fuel Consumption: 90,000 gals/year
Baseline NOx Emissions: 403 lbs/1,000 gals
(baseline emission factor for tugboat engines provided in Table V-5 above)
Reduced NOx Emissions: 242 lbs/1,000 gals
(40 percent reduction from 403 lbs/1,000 gals)
% operated in CA: 100%
(ton / 2,000 lbs): Converts lbs/year to tons/year

Estimated NOx reductions are:
90,000 gals/year * (403 - 242)lbs/1000 gals * 100% * ton/2,000 lbs = **7.3 tons/year**

<u>Cost Effectiveness Calculation</u>

Capital Costs to rebuild a 1,400 hp marine vessel engine w/o upgrade	$ 100,000
Capital costs to repower a 1,400 hp marine vessel engine	$ 250,000
Matching funds	$ 0

Incremental Project Cost: $ 250,000 - $ 100,000 = $150,000
Maximum Amount Funded: **$** 150,000 - $ 0 = $ 150,000
Capital Recovery Factor: $[(1 + 0.05)^{20} (0.05)]/[(1 + 0.05)^{20} - 1] = 0.08$
Annualized Cost: ($ 150,000 + $ 0) * (0.08) = $ 12,000/ year
Cost Effectiveness: ($ 12,000 / year) / (7.3 tons/year) = **$1,644/ ton**

The cost benefit for the example is less than $13,000 per ton of NOx reduced. This project would qualify for grant funds.

Example 2 – Auxiliary Engine Repower: Consider this same owner also wants to replace one auxiliary engine rated at 92 horsepower and has an energy consumption factor of 17 hp-hr/gal. The repowered engine is also rated at 92 horsepower but has an energy consumption factor of 19 hp-hr/gal and reduces uncontrolled NOx emissions by 30 percent. The project life is 20 years. The marine vessel owner estimates that the capital cost for rebuilding the auxiliary engine is about $2,000 and the replacement engine costs $15,000. The marine vessel owner also estimates that the annual fuel consumption for this engine is approximately 2,500 gallons.

Emission Reduction Calculation

Baseline NOx Emissions:	22 lbs/hr (auxiliary engines provided in Table V-6)
Baseline Energy Consumption Factor:	17 hp-hr/gal
Baseline Annual Fuel Consumption:	2,500 gals/year
Reduced NOx Emissions:	15.4 lbs/hr (30 percent reduction from 22lbs/hr)
Reduced Energy Consumption Factor:	19 hp-hr/gal
Reduced Annual Fuel Consumption:	(17 / 19)hp-hr/gal * 2,500 gal/yr = 2,237 gal/yr
Rated Horsepower:	92 hp
% operated in CA:	100%
(ton / 2,000 lbs):	Converts lbs/year to tons/year

Estimated NOx reductions are:
(22 lbs/hr / 92 hp * 17 hp-hr/gal * 2,500 gal/yr) – (15.4 lbs/hr / 92 hp * 19 hp-hr-gal * 2,237 gal/yr) * 100% * ton/2,000 lbs = **1.5 tons/year NOx emissions reduced**

Cost Effectiveness Calculation

Incremental Project Cost:	$ 15,000 - $ 2,000 = $ 13,000
Maximum Amount Funded:	$ 13,000
Capital Recovery Factor:	$[(1 + 0.05)^{20} (0.05)]/[(1 + 0.05)^{20} - 1] = 0.08$
Annualized Cost:	$ 13,000 * 0.08 = $ 1,040/ year
Cost Effectiveness:	($ 1,040 / year) / (1.5 tons/year)= **$ 693/ ton**

The cost benefit for the example is less than $13,000 per ton of NOx reduced. This project would qualify for grant funds.

E. Reporting and Monitoring

The district has the authority to conduct periodic checks or solicit operating records from the applicant that has received Moyer funds for each retrofitted or repowered marine engine. This is to ensure that the engine is operated as stated in the project application. Hence the applicant must maintain operating records and have them available to the district upon request. Records must contain, at minimum the following: marine vessel identification numbers; retrofit hardware model and serial numbers; nautical miles traveled in the district and California coastal waters; estimated fuel consumption in California coastal waters; estimated hours of operation in the California coastal waters; hours in idle; and maintenance and repair dates (or any servicing information). Records must be retained and updated throughout the project life and made available for district inspection.

F. References

1. Control of Emissions of Air Pollution from CI Marine Engines at or Above 37 Kilowatts, USEPA, May 11, 1998.

2. Control of Ship Emission in the South Coast Air Basin, Port of Los Angeles and Port of Long Beach, August 1994.

3. Emissions by Category, 1990 through 2010, ARB, November 1998.

4. Emissions Inventory Procedural Manual, Volume III, Methods for Assessing Area Source Emissions, September 1995, ARB, September 1995.

5. Marine Vessel Emissions Inventory and Control Strategies, Acurex Environmental for SCAQMD, December 12, 1996.

6. Reducing Marine Vessel and Port Emissions in the South Coast, U. S. EPA, EPA420-F-96-011, July 1996.

7. The California State Implementation Plan for Ozone, Volume II: The air Resources Board's Mobile Source and Consumer Products Elements, ARB, November 15, 1994.

CHAPTER VI.

STATIONARY AGRICULTURAL IRRIGATION PUMP ENGINES

This chapter presents the project criteria under the Carl Moyer Program for stationary agricultural irrigation pump engines (stationary agricultural irrigation pump engines). It also contains a brief overview of NOx emission inventory, current emission standards, available control technology, potential incentive projects eligible for funding, and emission reduction calculation and cost-effectiveness calculation methodologies.

A. Introduction

Stationary internal combustion engines used for agricultural purposes in California are primarily utilized to power irrigation water pumps. For the purposes of the Carl Moyer Program, these engines could be considered part of the off-road equipment, because off-road engines are often utilized in stationary agricultural applications. However due to the operating characteristics specific to stationary agricultural irrigation pump engines, they are evaluated separately from the off-road equipment category, which generally covers mobile equipment such as agricultural tractors, backhoes, excavators, trenchers, and motor graders.

Off-road engines can be divided into two major categories: (1) engines less than (<) 175 brake horsepower (bhp) and (2) engines greater than or equal to ($\geq$) 175 hp. The federal Clean Air Act Amendments (CAAA) of 1990 gave the United States Environmental Protection Agency (USEPA) exclusive authority to regulate new off-road engines. The amendments created a federal preemption that prevents states from adopting emissions standards or other requirements for off-road engines [CAA, section 209(e)]. However, Congress allowed California, upon receiving authorization from the USEPA, to adopt standards and regulations for preempted engines, with the exception of new farm and construction engines <175 hp. In other words, the ARB does not have authority to regulate off-road engines <175 hp used in farm operations. Also, the California Health and Safety Code (HSC) section 42310(e) prohibits local air districts or the State from requiring a permit for farm equipment.

According to federal definition, off-road engines do not include engines used in off-road applications which are considered stationary. Off-road engines, however, are a workable option for stationary agricultural applications. Therefore, for the purposes of the Carl Moyer Program, staff recommends that the guideline criteria for stationary agricultural irrigation pump engines be established within the framework of applying ARB/USEPA off-road engine emissions standards to stationary agricultural irrigation pump engines. Under the Carl Moyer Program, funding will be provided for voluntary reduction of NOx emissions from stationary agricultural irrigation pumps with engines 50 horsepower or greater. Section B of this chapter discusses specific criteria that must be met in order to qualify for funding from the Carl Moyer Program for this source category.

1. Emission Inventory

Agricultural irrigation pumps are powered electrically and with fuel-fired internal combustion engines. A 1995 report written by Sonoma Technology, Inc. for the SJVAPCD indicates 90 percent of irrigation pumps in the San Joaquin Valley are electrically powered. The remaining 10 percent are engine-driven pumps fueled most commonly with diesel and, to a lesser degree, with natural gas or propane. Diesel is most commonly used due to its lower cost and the limitations posed by inaccessibility to natural gas lines in certain rural areas. In general, stationary agricultural irrigation pump engines run an average of 10,000 hours before requiring an overhaul or rebuild. Depending on each engine owner's operating schedule and maintenance routine, this equates to a variety of engine lifetimes. Stationary agricultural irrigation pump engines generally have low annual operating hours, from 1,000 to 3,600 hours per year. Using this range of operating hours, an engine can run 3 to 10 years before rebuild. If an engine can be rebuilt 3 to 4 times, it is possible to get 30 to 40 years of life out of an engine. Once an engine has exhausted its useful life, the most common engine replacement practice by farmers, if they are still living or are still in the family business, is to purchase a rebuilt engine rather than a new engine.

Stationary agricultural irrigation pump engines can be considered a seasonal source of NOx emissions, although NOx emissions occur throughout the calendar year. Most NOx emissions occur throughout the spring and summer months during the primary crop growing period. In fact, seasonal NOx emissions from agricultural irrigation pump engines may be as high as 52 tons per day in the summer months throughout the San Joaquin Valley, according to a 1995 Sonoma Technology, Inc. report. According to the ARB's 1997 baseline NOx emission inventory for agricultural irrigation pumps powered by diesel engines, NOx emissions are 34 tons per day. ARB's estimated NOx emissions are based on data provided by San Joaquin Valley and Santa Barbara County Air Pollution Control Districts. Future emissions are projected to remain the same through 2010.

2. Emission Standards

Historically, the districts have not regulated emissions from stationary agricultural engines. In fact, district prohibitory rules for stationary internal combustion engines specifically exempt agricultural engines from the requirements of the district rules. Therefore, stationary agricultural engine emissions are largely uncontrolled, except in cases where engines of 1996 model year and newer are in use. These engines are subject to ARB/USEPA off-road diesel engine emission standards.

In January 1992, ARB adopted exhaust emission standards for 1996 and later model year off-road diesel cycle engines $\geq$175 hp. The USEPA has adopted virtually identical NOx emission standards for new off-road diesel cycle engines; however, the USEPA standards apply to off-road engines $\geq$50 hp. Table VI-1 lists both the ARB and USEPA standards. As shown in Table VI-1, these standards vary depending on the model year and the engine size. The combination of ARB and USEPA emission standards means that all of today's new off-road diesel cycle engines from 50 horsepower and greater have to be certified to meet a NOx emission standard of 6.9 g/bhp-hr.

ARB has also adopted optional NOx standards (emission reduction credit standards) for off-road diesel equipment. The optional NOx emission credit standards currently start at 5.0 g/bhp-hr and decrease in 0.5 g/bhp-hr increments. Beginning in 2001, the NOx emission credit standards for off-road diesel equipment will start at 4.5 g/bhp-hr and also decrease in 0.5 g/bhp-hr increments. Stationary agricultural engine projects eligible under the Carl Moyer Program must be certified to one of the emission reduction credit standards for 1996 and later model year engines. Certification must be conducted using the off-road test cycle.

Table VI-1
ARB and USEPA Exhaust Emission Standards
for New Off-Road Diesel Engines
(g/bhp-hr)

Model Year	Agency	Horsepower	NOx (g/bhp-hr)	PM (g/bhp-hr)
1996 – 2000	ARB/EPA	175-750	6.9	0.4
1997	EPA	100-<175	6.9	-
1998	EPA	50-<100	6.9	-
2000+	ARB/EPA	750+	6.9	0.4
2001+	ARB	175-750	5.8	0.16

3. Control Strategies

The purpose of this section is to discuss commercially available control technologies for stationary agricultural engine projects. The reduced-emission engines discussed are considered suitable as new engine purchases for repower opportunities. This section also provides information regarding reduced-emission engine technologies that can be purchased now, and/or have potential to become commercially available in the near term.

a. Emission-Certified Engines

New 1996 and later model year off-road diesel cycle engines from 50 horsepower and greater must comply with a NOx emission standard of 6.9 g/bhp-hr. The NOx emission standard for off-road diesel cycle engines with 175-750 hp sold in California will be reduced to 5.8 g/bhp-hr for the model year 2001 engines.

A viable and cost-effective way to reduce emissions from uncontrolled diesel engines is to substitute the engine (i.e., repower) with an emission-certified off-road compression-ignition or emission-certified off-road spark-ignition engine instead of rebuilding the existing engine to its original uncontrolled specifications. Emission-certified diesel engines are commercially available for off-road engines $\geq$50 hp that are covered under this program. The appropriate engine size for an irrigation pump will depend on a number of factors such as water demand and the size of the irrigation pump.

ARB has adopted exhaust emission standards for new large, off-road spark-ignition (LSI) engines on October 22, 1998, to be implemented beginning in 2001. The emission standards are applicable to non-preempted off-road spark-ignition engines >25 hp. The USEPA expects to propose comparable nationwide exhaust emission standards for this category of engines. The regulations require a certification process similar to that used for small off-road engines and heavy-duty off-road engines. The ARB regulations were approved recently and requirements will be phased-in over the next few years. Repowers with off-road spark-ignition engines would have to undergo applicable certification testing to verify emission levels. For purposes of the Carl Moyer Program, off-road spark-ignition engines would be required, at a minimum, to test to the off-road diesel emission standards for the applicable model year and horsepower rating.

b. Electric Motors

Another potentially cost-effective way to reduce emissions from uncontrolled engines is to replace the internal combustion engine with an electric motor instead of rebuilding the existing engine to its original uncontrolled specifications. Substituting an electric motor for an internal combustion engine on an agricultural irrigation pump significantly reduces emissions. Replacing an older electric motor for a newer electric motor on an agricultural irrigation pump does not reduce emissions. Irrigation pumps powered by electric motors are commercially available for various applications. In fact, 90 percent of current irrigation pumps are already powered by electric motors. Hence, the requirements for an electrification project to qualify for funding under the Carl Moyer Program are designed to target the replacement of the remaining 10 percent of internal combustion engines used in agricultural irrigation pumps. The viability of an electrification project will depend on a number of factors, including cost of electricity and proximity to an electric power grid.

c. Engine Retrofit Technology

Any retrofit technology must be certified by ARB before it can be sold in California, must be able to reduce NOx emissions by at least 15 percent, and must comply with established durability and warranty requirements. There are few retrofit technologies available for pre-1996 model year off-road diesel engines that would reduce NOx emissions from uncontrolled levels to the 6.9 g/bhp-hr NOx emission standard or lower. ARB recently pre-certified diesel engine retrofit kits for selected Detroit Diesel Corporation pre-1993 model year engines. The retrofit technology is certified to a NOx emission standard no greater than 5.8 g/bhp-hr. Currently, retrofit kits are available for a limited number of engine models some of which may be engines in the size range typically used for agricultural irrigation pumps. It is also possible that retrofit technologies that have been used to reduce NOx and PM emissions from on-road heavy-duty diesel engines could be used to control off-road engine emissions in some applications.

B. Project Criteria

The intent of the Carl Moyer Program is to provide early emission reductions from heavy-duty diesel engines. The approved project criteria have been designed to provide districts and equipment operators with a list of minimum qualifications that must be met in order for a project to qualify for funding. The main criteria for selecting a project are the amount of emission reductions, cost-effectiveness, and ability for the project to be completed within the timeframe of the program. The criteria also specify the method for calculating emission reductions and cost-effectiveness from reduced-NOx stationary agricultural engine projects. Reduced-NOx stationary agricultural irrigation engine projects that include engine repowers, new purchase or engine replacements with electric motors, or engine retrofits will be considered and evaluated for incentive funding.

The second through seventh project criteria listed below are new project criteria. These criteria were modified to clarify the type of repowers and retrofits allowed for agricultural irrigation pump engine projects under the Carl Moyer Program. The revised language allows for pre-1996 model year engines (≥50 horsepower) to be repowered with new off-road diesel engines certified to the current standard, new off-road spark-ignited engines that test at a NOx level that meets the current standard, or new electric motors. For these years, it also allows retrofit kits that are certified to the off-road emission standard for use on off-road engines. For 1996 and later model year engines, the repowered engine would be an engine certified to the off-road credit standards (for either diesel or spark-ignited engines), or an electric motor. Retrofit kits for 1996 and later model year engines would be certified to reduce NOx emissions by at least 15 percent. The project criteria have been modified to include a requirement that all engines be tested using approved ARB test procedures.

In general, stationary agricultural engine projects qualifying for evaluation must meet, at minimum, the following criteria:

- An engine must be 50 horsepower or greater which is equivalent to an electric motor 37 kilowatts or greater;

- A new purchase of a 2000 or later model year agricultural irrigation pump engine must have an electric motor.

- A repower or retrofit of a pre-1996 model year engine 50 horsepower and greater must be with:
  1) A new off-road diesel engine certified at the 6.9 g/bhp-hr NOx emission standard for off-road engines,
  2) A new off-road spark-ignited engine that tests at a NOx level that meets the off-road diesel engine standard (i.e., 6.9 g/bhp-hr),

3) A new electric motor, or
4) A kit that is certified to the off-road engine emission standards for use on off-road engines;

- A repower of an emission-certified off-road engine of model year~~s~~ 1996 and newer, must be with:
  1) A new off-road diesel engine certified at one of the applicable NOx emission credit standards listed in Table VI-2,
  2) A new off-road spark-ignition engine that tests at a NOx level that meets the off-road NOx emission credit standards, or
  3) A new electric motor;

- A retrofit of an emission-certified off-road engine of model year 1996 and newer, must be certified to reduce NOx emissions by at least 15% for use in off-road engines;

- Engines must be tested using ARB test procedures for off-road engines;

- The maximum project life when determining project benefits is as follows:

	Default without Documentation	Default with Documentation
New purchase/ Repower	7 years	10 years

A different project life may be selected for approval by ARB staff. However sufficient documentation must be provided to ARB that supports the selected project life based on the actual remaining useful life.

- Emission-certified engines of the model years 1996 and later, must be certified at one of the applicable NOx emission credit standards listed in Table VI-2;

Table VI-2
Project Eligibility Criteria
1996 and Later Model Year Engines

Engine Model Year	Engine Horsepower Rating (bhp)	Qualifying NOx Level (g/bhp-hr)
1996-2000	50-750	4.5
2000+	750+	4.5
2001+	50-750	4.0

- Electric motors must only replace internal combustion engines that are fueled with diesel, and the applicant must have documentation of payment to the local utility company for power installation. This requirement of documentation also applies to new installations;

- Reduced-emission engines or retrofit kits must be certified for sale in California and must comply with durability and warranty requirements. Qualified engines could include new ARB-certified engines or ARB-certified aftermarket part engine/control devices;

- NOx reductions obtained through this program must not be required by any existing regulations or any legally binding document (i.e., MOU, MOA, etc.);

- Funded projects must operate for a minimum of five years and the agricultural stationary engine must be registered with the district throughout the specified life of the project; and

- Projects must meet a cost-effectiveness criterion of $13,000 per ton of NOx reduced.

Priority should be given to stationary agricultural irrigation engine projects which result in the greatest amount of emission reductions (e.g., engine replacements with electric motors, engine repowers with certified engines, followed by engine retrofits). This is in line with the intent of the Carl Moyer Program to provide early emission reductions, and in turn, produce the greatest air quality benefit.

C. Potential Types of Projects

The primary focus of this category of the Carl Moyer Program is to achieve emission reductions from stationary diesel agricultural irrigation engines operating in California as early and as cost-effectively as possible. The following project criteria are designed to ensure that the emission reductions expected through the deployment of electric motors, reduced-emission engines, or retrofit technologies under this program are real and quantifiable. All projects must meet a cost-effectiveness criterion of $13,000 per ton of NOx reduced. In addition, diesel repower projects are also subject to a maximum dollar amount to be granted based on the horsepower rating of the engine. The project must be operated for at least five years from the time it is first put into operation.

1. New Purchase with Electric Motors

New purchases of agricultural irrigation pump are allowed if equipped with electric motors. This new agricultural irrigation pump with an electric motor would be compared to a new pump with an off-road diesel engine certified to the current off-road NOx emission standard.

2. Repower with Emission-Certified Engines

Purchases of new emission-certified diesel off-road engines to repower uncontrolled diesel engines are expected to be the most common type of project for stationary agricultural irrigation pump engines under this program due to their wide availability. Several air districts are currently funding these projects. Purchases of new off-road spark-ignition engines to repower uncontrolled diesel engines are also an option under this program.

Under the Carl Moyer Program, a stationary agricultural irrigation pump engine repower is substituting an existing uncontrolled engine with a new off-road engine certified to a current off-road NOx emission standard, or substituting an existing certified off-road engine with a new off-road engine certified to an optional ARB NOx emission credit standard. The NOx level that would qualify a stationary agricultural irrigation pump engine repower project for funding would depend on the engine model year and the engine size, as outlined in the criteria under section B and listed in Table VI-2. For repower projects, gasoline-to-diesel repowers will not qualify for the Carl Moyer Program.

Technology for diesel to alternative fuel repowers is available; however an extensive number of spark-ignition engines have not gone through certification testing. The applicant is allowed to test large spark-ignition engines, in lieu of certification since a number of these engines have not gone through certification testing. However, testing must be conducted according to ARB test procedures for off-road engines. The new ARB LSI regulations establish a testing program, and future USEPA regulations will establish a similar testing procedure. Carl Moyer Program funds will not cover the costs of certification testing. These costs would have to be absorbed by the applicant, engine manufacturer, or another outside source.

The emission factors under section D of this chapter have been revised to account for the new OFFROAD model. The new emission factors may prevent some repower projects from qualifying for funding. Hence the emission reduction requirement for repowers and retrofits has been modified to 15 percent.

3. Replacement with Electric Motors

Replacement of uncontrolled engines with electric motors is an option under the Carl Moyer Program. During the first year of the program, applications for electric motors were scarce. This was partly due to exclusion of infrastructure costs in determining the funding amount, which resulted in higher initial out-of-pocket costs to the applicant. In an electric pumping application, peripheral equipment is needed to supply electricity to the motor. The installed cost of a new certified diesel engine is comparable to the installed cost for an electric motor plus its necessary supporting components. Districts and utility companies have indicated that many diesel pump engines are situated next to existing electric lines, so no line extension would be needed. Considering the air quality benefits of electric motors, selected infrastructure costs for necessary equipment associated with the motor (e.g., control panel, motor leads, service pole with guy wire, connecting electric line) may be included in determining the grant amount awarded.

For more remotely located irrigation pumps, some utility companies offer monetary line extension credits. Where a credit applies, the customer is responsible for the cost of the line extension (generally charged on a per foot basis) beyond what is covered by the credit. In most cases, costs associated with electric line extensions may not be covered with Moyer funds. The only instance where Moyer funds may be used toward line extensions is where the maximum amount to be funded plus funded project costs do not exceed the $13,000/ton cost-effectiveness limit. In these cases, the funds applied toward a line extension, must come from the district and would count as matching funds. This may only be applied where the applicant faces out-of-pocket expense above the line extension credit allowance (i.e., the needed line footage is outside the maximum distance provided free of charge).

Diesel-to-electric motor repowering projects are subject to the cost-effectiveness criterion of $13,000 per ton of NOx emissions reduced, as well as other criteria presented in this guideline.

4. Retrofits

Retrofit means making modifications to the engine and/or fuel system such that the retrofitted engine does not have the same specifications as the original engine. Retrofit projects may be applicable to certain off-road diesel engine families. The most straightforward retrofit projects are those that could be accomplished at the time of engine rebuild. This might entail upgrading certain engine and/or fuel system components to result in lower emission configuration. It is possible that emission control technologies that have been used to reduce NOx and PM emissions from on-road heavy-duty diesel engines could be used to control off-road engine emissions in some applications. This type of project would qualify for funding if the engine retrofit kit for uncontrolled engines is certified to 6.9 g/bhp-hr NOx emission standard or less, for use in off-road engine applications.

Staff revised emission factors under section D of this chapter to account for the new OFFROAD model. The new emission factors may prevent some retrofit projects from qualifying for funding. Hence, emission reduction requirement for repowers and retrofits has been modified to 15 percent.

5. Sample Application

In order to qualify for incentive funds, districts will make applications available and solicit bids for reduced-emission projects from stationary agricultural engine operators. A sample application form is included in Appendix G. The applicant must provide at least the following information, as listed in Table VI-3 below:

Table VI-3 Minimum Application Information Stationary Agricultural irrigation pump Projects	
1. Air District: 2. Applicant Demographics Company Name: Business Type: Mailing Address: Location Address: Contact Number: 3. Project Description Project Name: Project Type: Equipment Function: 4. NOx Reduction Incremental Cost Effectiveness Analysis Basis: (Mileage/Fuel/Hours of Operation) 5. VIN or Serial Number: 6. Application: (Repower, Retrofit or New) 7. Annual Diesel Gallons Used: 8. Hours of Operation: 9. Old Engine Information Horsepower Rating: Engine Make: Engine Model: Engine Year:	10. New Engine Information Horsepower Rating: Engine Make: Engine Model: Engine Year: Fuel Type: 11. NOX Emissions Reductions Baseline NOx Emissions Factor (g/bhp-hr): NOx Conversion Factors Used: Reduced NOx Emissions Factor (g/bhp-hr): Estimated Annual NOx Emissions Reductions: Estimated Lifetime NOx Emissions Reductions: 12. Percent Operated in California: 13. Project Life (years): 14. Cost ($) of the Base Engine: 15. Cost ($) of Certified LEV Engine: 16. PM Emissions Reductions Baseline PM Emissions Factor (g/bhp-hr): PM Conversion Factors Used: Reduced PM Emissions Factor (g/bhp-hr): Estimated Annual PM Emissions Reductions: Estimated Lifetime PM Emissions Reductions: 17. District Incentive Grant Requested:

D. Emission Reduction and Cost-Effectiveness

1. Emission Reduction Calculation

In general, the emission reduction benefit represents the difference in the emission level of a baseline and reduced-emission engine. In situations where the model year of the equipment and the model year of the existing engine are different, the model year of the engine will be used to determine the baseline emission factor for emission reduction calculations. The emission level is calculated by multiplying an emission factor, a conversion factor and an activity level. Because the conversion factor and the activity level could be different for the baseline and reduced emission engine, the emission level should be calculated first and then the difference taken to determine the emission reduction. The examples in the previous version, where the emission reductions were simply based on the difference in emission factors, assumed that there was no change in the conversion factor or activity level. For a stationary agricultural irrigation pump, the activity level is either the annual hours of operation or fuel consumed. Qualification with the cost-effectiveness criteria will be based upon NOx emissions only. Calculations shall be done using either the fuel consumption method or hours of operation method described below consistent with the type of records that will be maintained over the life of the project.

In absence of manufacturer “guaranteed” emission factors, Table VI-4 lists the default baseline NOx emission levels for pre-1996 model year diesel engine repower and retrofit projects to be used when determining the NOx emission difference between the existing engine and the replacement engine. The new baseline NOx emission factors reflect the recently adopted emissions inventory for off-road large compression-ignited engines, greater than or equal to 25 horsepower. The OFFROAD model incorporated recent data and reflects currently adopted regulations. Manufacturers applied some of the technology advancements in the fuel management systems used in 1988 and newer on-road diesel-powered engine to similar off-road engines. Emission reductions from this technology are also reflected in the new emission factors. Also, the engine default load factor has changed from 0.75 to 0.65.

Table VI-4
Baseline NOx Emission factors for
Uncontrolled Off-Road Heavy-Duty Diesel Engines
(g/bhp-hr)

Model Year	50 –120 hp	120 + hp
Pre - 1988	13	11
1988 – 1996	8.75	8.17

The applicant would have the option of testing the baseline (uncontrolled) engine using an ARB approved test procedure to determine actual emissions. The maximum allowable baseline emissions for pre-1996 engines as determined through in-use testing is 13 g/bhp-hr ($\leq$120 hp) and 11 g/bhp-hr (>120 hp).

If the annual hours of operation are the basis for determining the emission reductions, the conversion factor is the horsepower of the engine multiplied by the load factor of the application and the activity level should be based on the actual hours of the equipment. The load factor is an indication of the amount of work done, on average, by an engine for a particular application, given as a fraction of the rated horsepower of the engine. The load factor is different for each application. If the actual load factor is known for an engine application, it should be used in calculating the emission reductions. Another variable in determining the emission reductions is the number of hours that the equipment operates a year as counted by an hour meter. If the load factor is not known, the default load factor listed in Table VI-5 should be used in the emission reduction calculation.

If the annual fuel consumption is used, an energy consumption factor should be calculated and the activity level should be based on actual annual fuel receipts or other documentation. The energy consumption factor converts the emission factor in terms of g/bhp-hr to g/gallon of fuel used. There are two ways of calculating the energy consumption factor: 1) by dividing the horsepower of the engine by the fuel economy in units of gallons/hour or 2) by dividing the density of the fuel by the brake-specific fuel consumption of the engine. A default energy consumption factor is listed in Table VI-6. While actual fuel receipts support the annual fuel consumption of the baseline engine, the annual fuel consumption of the reduced-emission engine is an estimate proportionate to the change in the energy fuel consumption factor. For example, a reduced-emission engine having an energy consumption factor of 20, replacing a baseline engine which uses 3,696 gallons/year and has an energy consumption factor of 17.56, would have an estimated annual fuel consumption of 3,234 gallons/year. Future fuel receipts or equivalent documentation should be submitted, throughout the project life, as verification of this estimate.

Table VI-5
Default Factors for Stationary Agricultural Irrigation Pumps
50+ Horsepower

Energy Consumption Factor (bhp-hr/gal)	17.56
Load Factor	0.65

2. Cost-Effectiveness Calculation

The portion of the cost for a repower project to be funded through the Carl Moyer Program is the difference between the total cost of purchasing and installing the new emission-certified engine or electric motor and the total cost of rebuilding the existing engine.

Only the amount of money provided by the program and any local district match funding is to be used in the cost-effectiveness calculations. The one-time incentive grant amount is to be amortized over the expected project life (at least five years) and with a discount rate of five percent. The amortization formula (given below) yields a capital recovery factor, which, when multiplied with the initial cost, gives the annual cost of a project over its expected lifetime.

Capital Recovery = $[(1 + i)^n (i)]/[(1 + i)^n - 1]$

Where, i = discount rate (5 percent)
n = project life (at least five years)

The discount rate of five percent reflects the opportunity cost of public funds for the Carl Moyer Program. This is the level of earning that could be reasonably expected by investing state funds in various financial instruments, such as U.S. Treasury securities. Cost-effectiveness is determined by dividing the annualized cost by the annual NOx emission reductions. These calculations are explained in detail in the next section of this chapter.

3. Examples

Example 1 – Agricultural Irrigation Pump Repower: Consider a farmer faced with the opportunity to replace a 1980 model year diesel engine rated at 120 horsepower used to power an irrigation water pump with a new, certified off-road diesel engine rated at 150 horsepower during the normal rebuild period. In this case, the cost of the new, emission-certified diesel engine is $7,900 whereas the cost to purchase a rebuilt engine would be $5,500. The cost of a non-resettable hour meter is $300. The old engine operated 2,000 hours annually. The project life is 7 years.

<u>Emission Reduction Calculation</u>

Baseline NOx Emissions:	13.0 g/bhp-hr
Baseline Horsepower:	120 hp
Baseline Load Factor:	65%
Reduced NOx Emissions:	6.9 g/bhp-hr
Reduced Horsepower:	150 hp
Reduced Load Factor:	120 hp / 150 hp * 65% = 52%
Annual Operating Hours:	2,000 hours/year
ton/907,200 grams:	Converts grams to tons

(13.0 g/bhp-hr * 120 hp * 0.65) – (6.9 g/bhp-hr * 150 hp * 0.52) * 2,000 hrs/yr * ton/907,200 g =
1.0 ton/year NOx emissions reduced

Cost-Effectiveness Calculations

The annualized cost is based on the portion of incremental project costs funded by the Carl Moyer Program, the expected life of the project (5 years at a minimum), and the interest rate (5 percent) used to amortize the project cost over the project life. The incremental capital cost to the operator for this purchase and the maximum amount that could be funded through the Carl Moyer Program fund are determined as follows:

Incremental Capital Cost	= \$ 8,200 - \$ 5,500 = \$ 2,700
Max. Amount Funded	= \$ 2,700
Capital Recovery	**=** $[(1 + 0.05)^7 (0.05)]/[(1 + 0.05)^7 – 1] = 0.17$
Annualized cost	= \$ 2,700 * 0.17 = \$ 459/year
Cost-Effectiveness	= (\$ 459/year)/(1.0 tons/year) = **\$ 459/ton NOx reduced**

The project meets the cost-effectiveness limit of $13,000 per ton NOx reduced. This project would qualify for the maximum amount of grant funds ($2,700).

Example 2 - Agricultural Irrigation Pump Repower: Consider a similar example, where an uncontrolled diesel engine (1980, 13 g/bhp-hr NOx) used to power an irrigation water pump is replaced with a new, certified off-road diesel engine (150 hp, 6.9 g/bhp-hr NOx). However, in this example the annual fuel consumption is provided. The energy consumption factor for the uncontrolled engine is unknown while the energy consumption factor for the new engine calculates to about 19 hp-hr/gal. The cost of the new, emission-certified diesel engine is $7,900 whereas the cost to purchase a rebuilt engine would be $5,500. The farmer lists in the application that the new engine will use 4,600 gallons of fuel annually for a project life of 7 years. Since this farmer lists fuel consumption, a non-resettable hour meter is not needed. The emission reduction and cost effectiveness for this project are calculated as follows:

Emission Reduction Calculation

Baseline NOx Emissions:	13.0 g/bhp-hr
Baseline Energy Consumption Factor:	17.56 hp-hr/gal
Baseline Annual Fuel Consumption:	4,600 gallons/year
Reduced NOx Emissions:	6.9 g/hp-hr
Reduced Energy Consumption Factor:	19 hp-hr/gal
Reduced Annual Fuel Consumption:	(17.56 / 19)hp-hr/gal * 4,600 gal/yr = 4,251 gal/yr
ton/907,200 grams	Converts grams to tons

[(13.0 g/bhp-hr * 17.56 hp-hr/gal * 4,600 gal/yr) – (6.9 g/bhp-hr * 19 hp-hr/gal * 4,251 gal/yr)] * ton/907,200 g = **0.54 tons/yr NOx emissions reduced**

Cost-Effectiveness Calculations

The annualized cost is based on the portion of incremental project costs funded by the Carl Moyer Program, the expected life of the project (7 years in this example), and the interest rate (5 percent) used to amortize the project cost over the project life. The incremental capital cost to the fleet operator for this purchase and the maximum amount that could be funded through the Carl Moyer Program fund are determined as follows:

Incremental Capital Cost = \$ 7,900 - \$ 5,500 = \$ 2,400
Max. Amount Funded = \$ 2,400
Capital Recovery **=** $[(1 + 0.05)^7 (0.05)]/[(1 + 0.05)^7 – 1] = 0.17$
Annualized cost = \$ 2,400 * 0.17 = \$ 408/year
Cost-Effectiveness = (\$ 408/year)/(0.54 tons/year) = **\$ 755/ton NOx reduced**

The project meets the cost-effectiveness limit of \$13,000 per ton NOx reduced. This project would also qualify for the maximum amount of grant funds (\$2,400).

Example 3 - Agricultural Irrigation Pump Electrification: Consider a farmer who applies for a Carl Moyer program grant for the purchase of an electric motor (150 hp, 0 g/bhp-hr NOx) to replace an uncontrolled diesel engine (208 bhp, 1980, 11 g/bhp-hr NOx) used to power an irrigation water pump. There is currently an electric power grid in the immediate vicinity of the pump and no electric line extension is needed. The installed cost of the new electric motor, control panel, motor leads, dropping a power line, and setting up a circuit breaker is \$14,602 whereas the cost to rebuild the old engine would be \$5,500. The cost of a non-resettable hour meter is \$300. The new engine will operate 2,000 hours annually, for a project life of 7 years. The emission reduction and cost effectiveness for this project are calculated as follows:

<u>Emission Reduction Calculation</u>

<u>Annual NOx Reductions (tons/year) =</u>

[(NOx Emission Factor * Load Factor * Horsepower)$_{\text{baseline}}$ – (NOx Emission Factor * Load Factor * Horsepower)$_{\text{reduced}}$] * Annual Hours of Operation * (ton/907,200 grams)

Where,

Baseline NOx Emission Factor:	11.0 g/bhp-hr
Reduced NOx Emission Factor:	0 g/bhp-hr
Load Factor:	65%
Baseline Horsepower:	208 hp
Reduced Horsepower:	150 hp
Annual Hours of Operation:	2,000 hours

Hence, estimated reductions are:

[(11.0 g/bhp-hr * 0.65 * 208 hp) – (0 g/bhp-hr * 0.65 * 150 hp)] * 2,000 hrs/yr * ton/907,200 g =
3.28 tons/year NOx emissions reduced

<u>Cost and Cost-Effectiveness Calculations</u>

The annualized cost is based on the portion of incremental project costs funded by the Carl Moyer Program, the expected life of the project (7 years in this example), and the interest rate (5 percent) used to amortize the project cost over the project life. The incremental capital cost to the fleet operator for this purchase, with Carl Moyer Program funds, is determined as follows:

Incremental Capital Cost	= \$14,602 - \$5,500 = \$9,102
Capital Recovery	$= [(1 + 0.05)^7 (0.05)]/[(1 + 0.05)^7 - 1] = 0.17$
Annualized Cost	= (0.17)(\$9,102) = \$1,547/yr
Cost-Effectiveness	= (\$1,547/yr)/(3.28 tons/yr) = **\$472/ton**

The project meets the cost-effectiveness limit of $13,000/ton NOx reduced. This project would qualify for the maximum amount of grant funds ($9,102).

Example 4 – Agricultural Irrigation Pump "Diesel-to-Natural Gas" Repower: The following example was added to illustrate the cost effectiveness calculations for a diesel-to-natural gas engine repower project.

Consider a farmer faced with the opportunity to replace a model year 1980 diesel engine rated at 165 hp used to power an irrigation water pump. The farmer is replacing the old uncontrolled engine (11 g/bhp-hr NOx) with a new, optionally certified off-road natural gas engine rated at 150 hp (4.5 g/bhp-hr NOx) during the normal rebuild period. In this case, the cost of the new, emission-certified off-road natural gas engine is $23,500 whereas the cost to purchase a rebuilt diesel engine would be $5,500. The cost of a non-resettable hour meter is $300. The new engine will operate 2,000 hours annually, for a project life of seven years. The emission reduction and cost effectiveness for this project are calculated as follows:

<u>Emission Reduction Calculation</u>

Baseline NOx Emissions	**=**	11.0 g/bhp-hr
Baseline Horsepower	**=**	165 horsepower
Baseline Load Factor	**=**	65%
Reduced NOx Emissions	**=**	4.5 g/bhp-hr
Reduced Horsepower	**=**	150 horsepower
Reduced Load Factor	**=**	71%
Annual Operating Hours	**=**	2,000 hours/year
Convert grams to tons	**=**	ton/907,200 grams

[(11.0 g/bhp-hr * 165 hp * 0.65) – (4.5 g/bhp-hr * 150 hp * 0.71)] * 2,000 hours/year * ton/907,200 g = **1.5 ton/year NOx emissions reduced**

<u>Cost-Effectiveness Calculations</u>

The annualized cost is based on the portion of incremental project costs funded by the Carl Moyer Program, the expected life of the project (seven years in this example), and the interest rate (5 percent) used to amortize the project cost over the project life. The incremental capital cost to the operator for this purchase and the maximum amount that could be funded through the Carl Moyer Program fund are determined as follows:

Incremental Capital Cost	= $ 23,800 - $ 5,500 = $ 18,300
Max. Amount Funded	= $ 18,300
Capital Recovery	= $[(1 + 0.05)^7 (0.05)]/[(1 + 0.05)^7 – 1] = 0.17$
Annualized cost	= $18,300 * 0.17 = $ 3,111/year
Cost-Effectiveness	= ($ 3,111/year)/(1.5 tons/year) = **$ 2,074/ton**

The project meets the cost-effectiveness limit of $13,000 per ton NOx reduced. This project would qualify for the maximum amount of grant funds ($18,300).

E. Reporting and Monitoring

Stationary agricultural engine operators participating in the Carl Moyer Program must keep appropriate records during the life of the project. During the project life, the district has the authority to conduct periodic checks or solicit operating records from the applicant that has received Moyer funds. This is to ensure that the engine is being operated as stated in the project application.

1. Reporting

The district has the authority to conduct periodic checks or solicit operating records from the applicant that has received Carl Moyer Program funds. This is to ensure that the engine is operated as stated in the program application. Hence, the applicant must maintain operating records and have them available to the district upon request. Records must be retained and updated throughout the project life and be made available to the district upon request. Annual records must contain, at a minimum, total actual hours operated, or estimated amount of fuel used. Where records of actual hours of operation are chosen, the engine must be equipped with a non-resettable hour meter. The cost of the hour meter shall be included in the capital cost of the engine for determining grant monies awarded. For electrification projects, the applicant must have documentation of payment to the local utility company for power installation.

2. Monitoring

Minimal monitoring may be necessary to ensure the program incentive monies are being applied toward the project as specified in the application. It is recommended that the districts conduct initial and/or periodic inspection of the equipment, especially when an electric motor is replaced for an internal combustion engine. To ease the tracking of the equipment over the life of the project, a district registration certificate could be issued to the equipment owner, consisting of minimal descriptive information.

F. References

1. California Air Pollution Control Officer's Association (CAPCOA) Portable Equipment
Rule Piston IC Engine Technical Reference Document, May 19, 1995.

2. California Air Resources Board, Stationary Source Division, Emissions Assessment Branch, Process Evaluation Section, *CAPCOA/ARB Proposed Determination of Reasonably Available Control Technology and Best Available Retrofit Control Technology for Stationary Internal Combustion Engines*, draft report, December 3, 1997.

3. Sierra Research, Inc., *Evaluation of VOC and NOx Control Measures*, Report No. SR98-04-01, April 2, 1998.

4. Sonoma Technology, Inc., *Emission Inventory of Agricultural Internal Combustion Engines Used for Irrigation in the SJVUAPCD*, Final Report STI-95240-1569-FR, August 1996.

5. United States Environmental Protection Agency, *AP-42, Compilation of Air Pollutant Emission Factors*, Fifth Edition, Volume I, Appendix A, January 1995.

CHAPTER VII.

FORKLIFTS

This document presents project criteria for forklift equipment funding eligibility under the Carl Moyer Memorial Air Quality Standards Attainment Program (Carl Moyer Program). Also included is an overview of applicable regulations pertaining to forklifts, available control technology, examples of potential projects, and emission reduction and cost-effectiveness calculation methodologies.

A. Forklift Equipment

Forklifts are used in a wide variety of applications, including, but not limited to, manufacturing, construction, retail, meat and poultry processing, lumber and building supplies, trades, agriculture, and a variety of warehouse operations. Forklifts can be powered by electric motors or by internal combustion engines (ICEs).

The Industrial Truck Association (ITA) has defined seven classes of forklifts. These classes are defined by the type of engine, work environment (indoors, outdoors, narrow aisle, smooth or rough surfaces), operator positions (sit down or standing), and equipment characteristics (type of tire, maximum grade). Several classes are further divided by operating characteristics. The following are the forklift classifications:

- ***Class 1*** are electric motor trucks with cushion or pneumatic (air filled) tires. Class 1 forklifts include four subcategories, or lift codes, which are:

Lift Code 1	Counterbalanced rider type, stand-up
Lift Code 4	Three-wheel electric, sit down
Lift Code 5	Counter balanced rider, cushion tire, sit-down
Lift Code 6	Counter balanced rider, sit-down rider (includes pneumatic tire models)

- ***Class 2*** forklifts are electric motor narrow aisle trucks with solid tires.

- ***Class 3*** forklifts include electric hand trucks or hand/rider trucks with solid tires.

- ***Class 4*** forklifts are ICE sit down rider forklifts with cushion tires and generally suitable for indoor use on hard surfaces.

- ***Class 5*** forklifts are ICE sit down rider forklifts with pneumatic tires. These are typically used outdoors, on rough surfaces, or significant inclines.

- ***Class 6*** trucks can be either electric or ICE powered. These are ride on units with the ability to tow at least 1,000 pounds. This class is designed to tow cargo rather than lift it.

- ***Class 7*** trucks are rough terrain forklift trucks with pneumatic tires. Class 7 trucks are almost exclusively powered by diesel engines, and are used outdoors.

B. Emission Inventory

According to the ARB off-road emissions inventory, there were more than 39,000 ICE forklifts with engines greater than 50 horsepower used in industrial applications in California in 1995. These estimates do not include large terrain forklifts or forklifts used at airport operations. Estimates for forklifts used in airport operations are discussed in the document pertaining to airport ground support equipment. Total NOx emissions from industrial forklifts greater than 50 horsepower in California are estimated to be 62.1 tons per day in 1995, and are estimated to be 37.1 tons per day in 2010. ICE forklifts are fueled with gasoline, propane, natural gas, or diesel.

Table VII-1 contains ICE forklift population and NOx emission estimates for 1995. The emission estimates for propane, gas and compressed natural gas forklifts have already been approved by ARB. Emission estimates for diesel forklifts are pending Board approval.

Table VII-1
1995 Population and NOx Emission Estimates
For Industrial Forklifts with Internal Combustion Engines
California and South Coast Air Basin Data

Horsepower Range	Year	Fuel	Population		NOx Emission (tons per day)	
			SCAB	State	SCAB	State
50≤ hp <120	1995	Gasoline	4,610	9,318	6.5	13.1
50≤ hp <120	1995	CNG, Propane	9,914	17,638	12.3	22.0
50≤ hp <120	1995	Diesel	4,990	10,060	10.1	19.4
120≤ hp <175	1995	Gasoline	168	340	0.6	1.1
120≤ hp <175	1995	CNG, Propane	362	645	1.0	1.7
120≤ hp <175	1995	Diesel	474	956	1.5	2.9
>175 hp	1995	Diesel	205	414	1.0	1.9
Total			**20,723**	**39,371**	**33.0**	**62.1**

The ARB inventory does not contain information on the number of electric forklifts in California. Most of the information on the type of forklifts bought and used is considered to be confidential within the industry. Forklift population estimates that have been developed by Electric Power Research Institute (EPRI) and other sources generally rely on ITA shipment data. Data reviewed by ARB staff indicates that there are about 70,000 electric forklifts in California. Roughly 50,000 of those are the smaller (class 3) hand trucks and narrow aisle trucks, and about 20,000 of those are electric rider forklifts. Electric forklifts have zero exhaust emissions.

C. Emission Standards

Emission standards for forklifts are contained in ARB and United States Environmental Protection Agency's (U.S EPA) emission standards for off-road equipment. Internal combustion engine forklifts can either be powered by diesel engines (compression-ignited engines) or by spark-ignited engines (which use gasoline, compressed natural gas, or propane fuel). There are separate emission standards for large spark-ignited engines and compression-ignited engines.

Off-road equipment is also split into two broad categories: less than 175 horsepower, and equal to or greater than 175 horsepower. Both of these categories include forklifts. Currently, ARB is preempted from regulating new farm and construction equipment less than 175 horsepower. However, ARB has the authority to regulate off-road equipment equal to or greater than 175 horsepower and non-preempted off-road equipment less than 175 horsepower.

1. Large Spark-Ignited Off-Road Engine Standards

Forklifts with spark-ignited engines are commonly used indoors, and typically have lift capacities between 3,000 and 16,000 pounds. A report prepared for the Gas Research Institute indicated that about 45% of spark-ignited forklifts (class 4 and 5) have engines rated 50 horsepower or lower. On an ICE forklift, a 50 horsepower engine generally has a 6,000 pounds lift capacity or greater. Propane is the fuel that is most widely used in spark-ignited engines, compared to gasoline or compressed natural gas.

Spark-ignited engines greater than 25 horsepower are classified as large spark-ignited engines by ARB. Current model year large spark-ignited engines are not subject to any ARB or USEPA emission standards. ARB has approved standards for new large spark-ignited off road engines to be implemented beginning with the 2001 model year. The regulations establish exhaust emission standards and test procedures. Table VII-2 contains the emission standards applicable to large spark-ignited engines that were approved by ARB.

Table VII-2
Exhaust Emission Standards
New Large Spark-ignited Engines

Year	Engine Size	NMHC + NOx (g/bhp-hr)	CO (g/bhp-hr)	Durability Period
2002 & later	<1.0 liter	9.0	410	1000 hours or 2 years
2001-2003 (Phase-in)	>1.0 liter	3.0	37	N/A
2004-2006	>1.0 liter	3.0	37	3500 hours or 5 years
2007 & later	>1.0 liter	3.0	37	5000 hours or 7 years

** The standard for in-use compliance for engine families certified to the standards noted above shall be 4.0 gbhp-hr (5.4 g/kW-hr) hydrocarbon plus oxides of nitrogen and 50.0 g/bhp-hr (67 g/kW-hr) carbon monoxide for a useful life of 5000 hours or 7 years.*

2. Diesel Off-Road Engine Standards

Compression-ignition engines (diesel) are often used to power forklifts that have large payload requirements. Almost all diesel forklifts have lift capacities over 6,000 pounds, and are available with lift capacities exceeding 40,000 pounds.

Diesel forklifts are subject to off-road compression ignition engine standards. ARB has adopted emission standards for off-road diesel cycle engines equal to or greater than 175 horsepower. The USEPA has adopted NOx emission standards for off-road diesel cycle engines at or above 50 horsepower. The USEPA rule aligns with California's first tier regulations for engines 175 horsepower and greater and took effect in 1996. The USEPA rule also took effect in 1997 for off-road diesel cycle engines at or above 100 horsepower but less than 175 horsepower and in 1998 for off-road diesel cycle engines at or above 50 horsepower but less than 100 horsepower. The combination of ARB and USEPA emission standards means that all of today's new off-road diesel cycle engines, including forklifts, 50 horsepower and greater have to be certified to meet a NOx emission standard of 6.9 g/bhp-hr.

USEPA, ARB, and off-road diesel engine manufacturers have signed a Statement of Principles (SOP) that sets forth comprehensive future emission standards for compression ignition (diesel) off-road engines. The SOP provides for NOx, PM, and carbon monoxide (CO) emission standards for new engines to be phased-in from 2003 through 2008. USEPA has adopted regulations for off-road diesel equipment consistent with the emission levels contained in the SOP. The ARB intends to revise California's regulations for off-road equipment to harmonize with federal regulations. Table VII-3 contains the applicable USEPA standards for off-road diesel engines.

Table VII-3
USEPA Exhaust Emission Standards for Off-Road Diesel Engines 50≤hp<175

Rated Power (horsepower)	NOx and PM Emission Standards (g/bhp-hr)							
	1997/8		2003/2004		2007		2008	
	NOx	PM	NMHC +NOx	PM	NMHC + NOx	PM	NMHC + NOx	PM
50 ≤ hp < 100	6.9	--	5.6	0.30	5.6	0.30	3.5	0.30
100≤ hp < 175	6.9	--	4.9	0.30	3.0	0.22	3.0	0.22

D. Electric Forklifts

Electric forklifts include electric motor trucks with cushion or pneumatic tires (Class 1); electric motor narrow aisle trucks (Class 2); and electric hand trucks or hand/rider trucks (Class 3). Class 1 electric forklifts are available in a wide variety of lift capacities from 3,000 pounds to 20,000 or greater pounds. According to market data evaluated by

ARB, most class 1 forklifts sold today in the U.S. are in the 3,000-6,000 pound lift capacity range. There does not appear to have been a large penetration of electric class 1 forklifts with lift capacities greater than 6,000 pounds in the current California or U.S. market.

Electric forklifts are most typically used in indoor materials handling applications that do not require large lift capacities (i.e., warehouse/retail operations). There are some applications where electric forklifts are used extensively, primarily for worker safety. These applications include confined spaces, cold storage, and food retail (primarily grocery stores).

Although electric forklifts are primarily designed for indoor operations, a number of manufacturers are also including equipment features which enable electric models to be used a wider variety of environments. These features include pneumatic tires (air filled), which allow the forklift to be used on unimproved surfaces. Another feature is water proofing trucks or sealing the electronic compartment to make them more water resistant for outdoor conditions. Class 1 forklifts (electric) compete directly with ICE forklifts for many of the same work applications.

Electric forklifts have no exhaust emissions, and extremely low upstream (power plant) emissions. Thus electric forklifts can provide significant air quality benefits. EPRI has prepared several reports on electric forklifts that identify other benefits of electric forklift usage besides improved air quality. One benefit is that electric forklifts have lower life cycle costs when compared with ICE models. This is due to lower maintenance costs, lower fueling costs, and longer useful life for an electric forklift. Although the initial capital cost is higher for an electric forklift as compared with the ICE forklift, the incremental cost can be recouped during the useful life of the electric forklift. Because of the financial benefits to the end user, electric forklifts are already prevalent in the general market.

E. Control Strategies

Electric forklifts have been widely used for a number of years in the United States. Increasing the use of electric forklifts by replacing ICE forklifts with electric forklifts would reduce NOx emissions. Replacing an older electric forklift with a newer electric model, however, does not reduce emissions. The project criteria for forklifts have been designed to encourage the replacement of an ICE forklift with an electric forklift and to exclude projects where "electric to electric" replacements are likely to occur or where electric forklifts already dominate the market.

1. Forklift Class

Class 1 forklifts are the electric models that compete with ICE forklifts because they are similar in design and specification. Class 1 forklifts can be used in many of the same work applications as an ICE (class 4 or 5) forklift. Increasing the use of class 1 forklifts relative to class 4 and 5 forklifts would reduce NOx emissions. Class 2 and 3 forklifts generally do not compete with ICE forklifts. Since these classes are solely electric forklifts, and “electric-to-electric” replacements do not yield NOx reductions, Class 2 and 3 would be excluded from funding under the Carl Moyer Program.

Rough terrain forklifts (Class 7) are primarily powered by diesel engines. Electric or alternatively fueled options are not currently available for Class 7 forklifts. Hence, Class 7 forklifts would be excluded from the Carl Moyer Program.

2. Industry Application

The most viable control strategies would include funding electric forklifts that replace ICE forklifts, where electric forklifts are not commonly used. These control strategies would include construction, millwork, cargo handling, lumber, plywood, foundries, and metal work.

Conversely, there are several applications where electric forklifts are used extensively, as compared to ICE forklifts. These industrial applications include confined spaces (such as freezers), cold storage, and food retail (primarily grocery stores). Since electric forklifts are commonly used in these industrial applications, “electric-to-electric” replacements would also be common. Hence, forklift purchases or replacements in industries whose primary business includes confined spaces, cold storage, and food stores are excluded from the Carl Moyer Program.

3. Forklift Rental

Market data prepared for the Gas Research Institute indicates several interesting trends regarding forklift usage and ownership. Approximately 55% of Class 1 and 2 forklifts are owned by the end user, 15% are rented (short-term rentals), and 30% are full service leases. The proportion of purchased, rented, and leased ICE forklifts (class 4 and 5) is very similar.

Full service leases are an attractive option to many companies because they reduce the up-front capital costs associated with the purchase of new forklift equipment. Rented and leased-to-own equipment can be deployed in a wide variety of fleets and work applications. There is no practical way to ensure that leased or rented electric forklifts are replacing an ICE forklift, and not an "electric-to-electric" replacement. Therefore, rented and leased equipment is currently excluded under the project criteria

There are a number of issues associated with leased equipment, such as free-ridership (electric-to-electric replacements), enforcement, and incremental capital costs. Due to the lower maintenance and operation costs associated with leasing an electric forklift over an ICE forklift, there can be some cost benefits with leasing an electric forklift. Since reduced costs are already an incentive to the end user, it is hard to determine if an electric forklift would have still been leased without Carl Moyer Program funding as the incentive. Furthermore, it is also difficult to determine the appropriate incremental cost to fund, since an electric forklift may already provide some incentive to the end user. Although leased equipment may seem to be a viable project, it is still necessary to ascertain the conditions under which leased equipment could be incorporated into the Carl Moyer Program. Therefore, only leased-to-own equipment for certain projects would be eligible for funding under the Demonstration Program (discussed later in this document).

4. Hours of Usage

The report prepared for the Gas Research Institute also indicates that the annual hours of usage varies significantly between industries. For electric forklifts, the range varies from 500 hours to 3,500 hours a year, with an average of about 2,250 hours/year. The average annual hours of usage for an ICE forklift are 1,900 hours/year.

The Gas Research Institute report also estimated that two thirds of electric forklifts are purchased new, while one third are purchased used. New electric forklift purchasers often record twice the operating hours as used forklift purchasers. Because of the reduced usage and life expectancy of older equipment, only the purchase of new electric forklifts will be funded under the Carl Moyer Program. In addition, all projects will be required to have an hour meter on each forklift, and track annual hours of operation for the project life (five years). This is to ensure that the emission benefits of the project are realized.

5. Battery Charger

One good indication that a business or fleet is not currently using an electric forklift is whether they have battery chargers. In order to ensure that the Carl Moyer Program is funding replacement of an ICE forklift with an electric forklift, and not an electric to electric replacement, all projects will be required to purchase battery chargers. The number of chargers purchased must correspond to the number of forklifts purchased. There may be some cases, however, where a charger for every forklift is not necessary. For example, operations that incorporate daily multiple shifts, or facilities that have fast-charging equipment. Applicants showing that there is a need to incorporate an amount of chargers that do not correspond to the amount of forklifts will be evaluated on a case-by-case basis.

6. Multiple Shift Operations

According to the Gas Research Institute, on average, both electric and ICE forklifts operate 1.5 shifts a day, five days a week. Sixty-nine percent of class 1 and 2 (electric) forklifts operate one shift a day, 16% operate two shifts, and 15% operate three shifts. According to the survey, on average, an electric (class 1 or 2) forklift is recharged after 11 clock (not meter) hours. Thus, electric forklifts operating in multiple shifts typically use multiple battery packs and battery change out equipment. For ICE forklifts, 59% operate one shift, and almost 40% operate two shifts. The average propane tank is replaced or refilled after 15 hours. Both electric and ICE forklifts can sit idle for a significant portion of the shifts during which they are used. Furthermore, the usage pattern can vary from continual use to 4 or 5 hours per shift. The Carl Moyer Program will fund the purchase of one battery pack per forklift purchased. Applications indicating a request to fund multiple battery packs that may be needed for multiple shift operations will be considered on a case-by-case basis. Documentation indicating the extensive use will be required.

7. New and Expanded Facilities

For new and expanding facilities it is difficult to determine the level of commitment for increasing the purchase of electric forklifts over ICE forklifts. In order for a company with multiple facilities to be funded under the Carl Moyer Program, the company must demonstrate a commitment to significantly increase the percent of electric forklifts over ICE forklifts in the company's fleet. For expanding facilities, companies must demonstrate that the expansion includes a physical change, such as a 25 percent increase in square footage.

F. Project Criteria

In order for a forklift project to qualify for funding under the Carl Moyer Program, the project must meet the specific criteria listed below. In general, the incremental cost of all projects must meet a cost-effectiveness criterion of $13,000 per ton of NOx reduced. The forklift must also be operated for at least five years from the time it is first put into operation, and for at least 75 percent of the time in California.

Funding for electric forklifts with a lift capacity under 6,000 pounds has been provided via a demonstration project in the SCAQMD for the first two years of the Carl Moyer Program. Under this demonstration program, SCAQMD staff was successful at incentivizing electric forklift projects that would not likely have occurred without funding. In addition, the SCAQMD staff determined that it was appropriate to set a cost-effectiveness criterion of $3000 per ton of NOx reduced for forklift projects. Funding for forklifts with lift capacities of 3,000 through 6,000 pounds would be allowed under the Carl Moyer Program, however those forklift projects would have separate project criteria and a cost-effectiveness criterion of $3,000 per ton of NOx reduced.

The following criteria are listed for forklift projects based on lift capacity.

<u>Forklifts with a lift capacity of 6,000 pounds or greater</u>

- Eligible equipment are four wheel counter-balanced sit-down electric forklifts, rated class 1, lift codes 5 or 6, plus one battery pack for each forklift purchased.

- For existing, new, and expanding facilities, all forklifts must be purchased new, and rated for a minimum lift capacity of 6,000 pounds or greater.

- All expanding facilities must provide documentation that indicates a significant physical change in the facility, such as a 25 percent or greater increase in square feet.

- All eligible projects must also include the installation of battery chargers that correspond to the number of forklifts purchased. Battery chargers are considered infrastructure and cannot be included as project costs.

- All eligible projects will be required to have an hour meter on each forklift, and track annual hours of operation.

- All eligible projects must sign a declaration that the applicant is not replacing an old electric forklift with a new electric forklift.

- For existing facilities, the ICE forklift which is being replaced must have an engine rated for 50 horsepower or greater.

- NOx reductions obtained through this program must not be required by any existing regulations or binding agreements.

- Forklifts used in commercial (passenger) and military airport operations were not included in the forklift emissions inventory. They may be eligible for funding provided they meet both forklift and GSE project criteria.

- All applicants must purchase new forklifts for use by the applicant. Organizations or businesses that rent or lease-to-own are not eligible for funding. Rental or leased equipment costs are also not eligible for funding.

- The following are not eligible for funding under this program: food retail stores, cold storage, and confined space operations (such as freezers).

- The following forklift purchases are not eligible: stand up electric forklifts (class 1, lift code 1), three-wheel electric sit-down rider (class 1, lift code 4), narrow aisle electric forklifts (class 2) or hand/rider trucks (class 3).

- The maximum cost-effectiveness is $13,000 per ton of NOx reduced.

- When calculating project benefits, the allowable project life for a forklift project is five years.

<u>Forklifts with a lift capacity 3,000 through 6,000 pounds</u>

- Lift capacities of 3,000 to 5,999 that are new purchases or leased-to-own

- Prior to funding, at least one site visit will be required. The site visit will include an evaluation of a number of factors, such as 1) whether or not fuel switching is occurring; 2) whether or not the electric forklift would be replacing an ICE forklift; 3) the customer plans for ICE forklifts that are replaced; and 4) hours of operation. Funding will not be approved if the initial site visit determines that the electric forklifts are replacing older electric forklifts, and not ICE forklifts.

- As a condition of funding, the applicant will agree to participate in the monitoring program as described in Section I.

- All projects that include leased-to-own equipment must have a signed contract with the air district that specifies the end user will keep and use the equipment for five years.

- For reporting purposes, information on these forklifts must include data on hours of operation (i.e., hours of use, kilowatt-hour use, and hours in idle); the relationship between horsepower and lift capacity; the cost of charging equipment (including installation) as it impacts the increased market penetration of electric forklifts, and recommendations for how leased-to-own equipment could be incorporated into future project criteria. Data will be presented so that all proprietary and confidential information is protected.

- All projects must meet all Carl Moyer general requirements, which include a minimum project life of five years, and a minimum of 75% equipment operation in California.

- The maximum cost effectiveness for a forklift project under the demonstration program is $3,000 per ton of NOx reduced.

- When calculating project benefits, the allowable project life for a forklift project is five years.

G. Sample Application

In order to qualify for incentive funds, districts will make applications available and solicit bids for reduced-emission projects from forklift operators. A sample application form is included in Appendix H. The applicant must provide at least the following information, as listed in Table VII-4 below:

Table VII-4 Minimum Application Information Forklift Projects	
1. Air District: 2. Applicant Demographics Company Name: Business Type: Mailing Address: Location Address: Contact Number: 3. Project Description Project Name: Engine Function: VIN or Serial Number: Is the electric forklift replacing an older non-electric forklift, part of operation or facility, or facility expansion, or for a brand new facility operations Maximum rated life capacity (lbs) **4.** Application: (Repower, Retrofit or New) 5. NOx Emissions Reductions Baseline NOx Emissions Factor (g/bhp-hr): NOx Conversion Factor Used: Reduced NOx Emissions Factor (g/bhp-hr): Estimated Annual NOx Emissions Reductions: Estimated Lifetime NOx Emissions Reductions: 6. Does the applicant rent or lease forklifts to others? 7. Cost of forklift (including 1 battery pack) 8. Cost of charging equipment:	9. Cost ($) of the Base Engine (non-electric): 10. Cost ($) of Certified Engine: 11. Annual Hours of Operation: 12. Percent Operated in California: Project Life (years): 13. ICE Forklift Being Replaced (if an existing business) Horsepower Rating: Manufacturer: Model: Year: 14. New Engine Information Horsepower Rating: Engine Make: Engine Model: Engine Year: Manufacturer and model number of new forklift: Type of forklift purchases: 15. PM Emissions Reductions Baseline PM Emissions Factor (g/bhp-hr): PM Conversion Factor Used: Reduced PM Emissions Factor (g/bhp-hr): Estimated Annual PM Emissions Reductions: Estimated Lifetime PM Emissions Reductions: 16. District Incentive Grant Requested:

H. Emission Reduction and Cost-Effectiveness

1. Emission Reduction Calculation

The emission reduction benefit will be calculated for NOx emissions only and will be determined using the annual hours of operation. Annual NOx emission reductions are determined by multiplying the difference in the NOx emission levels by the rated horsepower of the engine, the load factor, and the hours the engine is expected to operate per year. The load factor is an indication of the amount of work done, on average, by an engine in a particular application, given as a fraction of the rated horsepower of that engine. If the actual load factor is known for an engine it should be used in calculating emission reductions. If the actual load factor is not known, the default value of 0.30 will be used; this is the load factor used in the ARB inventory for all non-construction forklifts (all fuels). Another variable in determining emission reductions is the number of hours the equipment operates. If actual hours of equipment operation are not available, the default value of 1,900 annual hours should be used to calculate emission reductions.

Table 5
Baseline Emission Rates for Forklift Engines

Rated Power (horsepower)	Type of Engine	NOx Emission Rates
>50 horsepower	Compression ignition (diesel)	6.9 (g/bhp-hr)
> 50 horsepower	Large Spark-ignited (propane) Uncontrolled	10.5 (g/bhp-hr)
> 50 <120 horsepower	Large Spark-ignited (gasoline) Uncontrolled	11.8 (g/bhp-hr)
>120 horsepower	Large Spark-ignited (gasoline) Uncontrolled	12.9 (g/bhp-hr)

2. Cost-Effectiveness Calculation

The portion of the cost for an electric forklift project to be funded through the Carl Moyer Program is the difference between the cost of purchasing a new electric forklift and buying a conventional forklift. Only the amount of money provided by the Carl Moyer program and any local district match funds can be used in the cost-effectiveness calculations. The one-time incentive grant amount is to be amortized over the expected project life (at least five years) with a discount rate of five percent. The amortization formula (given below) yields a capital recovery factor, when multiplied with the initial capital cost, gives the annual cost of a project over its expected lifetime.

Capital Recovery Factor (CRF) = $[(1 + i)^n (i)] / [(1 + i)^n - 1]$

Where, i = discount rate (5 percent)
n = project life (at least five years)

The discount rate of five percent reflects the opportunity cost of public funds for the Carl Moyer Program. This is the level of earning that could be reasonably expected by investing state funds in various financial instruments, such as U.S. Treasury securities. Cost-effectiveness is determined by dividing the annualized cost by the annual NOx emission reductions. Example calculations for forklift projects are provided below.

3. Examples

For the purposes of explaining the emission reduction and the cost effectiveness calculations from a particular forklift project, two examples are presented below. The first example describes the calculations based on replacing a diesel forklift with an electric counter balanced sit down rider electric (class 1) forklift, and the second example shows calculation for the replacement of a propane forklift.

Example 1 – Calculations for replacement of a diesel forklift, based on hours of operation.

A forklift owner applies for a Carl Moyer Program grant for the purchase of a new counter balanced sit down rider electric forklift to replace a diesel powered ICE forklift. The forklift owner has decided to purchase a new electric forklift instead of purchasing a new diesel forklift certified to a 6.9 g/bhp-hr NOX standard. The cost of the new electric forklift is $39,900, plus $4000 for the battery, whereas the cost to buy a new diesel ICE forklift is $35,730. The new forklift will operate 1900 hours annually and will operate 100 percent of the time in California.

Emission Reduction Calculation

Baseline NOx Emissions:	6.9 g/bhp-hr
Reduced NOx Emissions:	0 g/bhp-hr
Rated Horsepower:	90 hp
Annual Operating Hours:	1,900 hours
Load Factor:	0.30
% Operated in CA:	100%
(ton/907,200 g):	Converts grams to tons

Baseline Engine
6.9 g/bhp-hr * 90 hp * 1,900 hours/year * 0.30 * 100% * ton/907,200g = 0.39 tons/year

Reduced Engine
0 g/bhp-hr * 90 hp * 1,900 hours/year * 0.30 * 100% * ton/907,200g = 0.0 tons/year

0.39 tons/year – 0.0 tons/year = **0.39 tons/year NOx reduced**

Cost-Effectiveness Calculations

The annualized cost is based on the portion of incremental project costs funded by the Carl Moyer Program, the expected life of the project (5 years at a minimum), and the interest rate (5 percent) used to amortize the project cost over the project life. The incremental capital cost to the equipment owner for this purchase and the maximum amount that could be funded through the Carl Moyer Program fund are determined as follows:

Total cost of new electric forklift:	$ 39,900 + $ 4,000 = $ 43,900
Incremental Capital Cost:	$ 43,900 - $ 35,730 = $ 8,170

Max. Amount Funded:	\$ 8,170
Capital Recovery:	$[(1 + 0.05)^5 (0.05)]/[(1 + 0.05)^5 – 1] = 0.23$
Annualized cost:	\$ 8,170 * 0.23 = \$ 1,879/year
Cost-Effectiveness:	(\$ 1,879/year)/(0.39 tons/year) **= \$ 4,818/ton**

The project meets the cost-effectiveness limit of \$13,000 per ton NOx reduced and is eligible for an incentive amount of \$8,170.

Example 2– Calculations for replacement of a propane forklift, based on hours of operation.

A forklift owner applies for a Carl Moyer Program grant for the purchase of a new counter balanced sit down rider electric forklift to replace a propane powered ICE forklift. The forklift owner has decided to purchase a new electric forklift instead of purchasing a new propane forklift with uncontrolled emissions of 10.5 g/bhp-hr. The cost of the new electric forklift is \$30,000 (including one battery pack), whereas the cost to buy a new propane forklift is \$25,000. The new forklift will operate 1900 hours annually and will operate 100 percent of the time in California.

<u>Emission Reduction Calculation</u>

Baseline NOx Emissions:	10.5 g/bhp-hr
Reduced NOx Emissions:	0 g/bhp-hr
Rated Horsepower:	60 hp
Annual Operating Hours:	1,900 hours
Load Factor:	0.30
% Operated in CA:	100%
(ton/907,200 g):	Converts grams to tons

Baseline Engine
10.5 g/bhp-hr * 60 hp * 1,900 hrs/yr * 0.30 * 100% * ton/907,200g = 0.40 tons/year

Reduced Engine
0 g/bhp-hr * 60 hp * 1,900 hrs/yr * 0.30 * 100% * ton/907,200g) = 0.0 tons/year

0.40 tons/year – 0.0 tons/year = **0.40 tons/year NOx reduced**

<u>Cost-Effectiveness Calculations</u>

The annualized cost is based on the portion of incremental project costs funded by the Carl Moyer Program, the expected life of the project (5 years at a minimum), and the interest rate (5 percent) used to amortize the project cost over the project life. The incremental capital cost to the equipment owner for this purchase and the maximum amount that could be funded through the Carl Moyer Program fund are determined as follows:

Total cost of new electric forklift	= \$ 30,000
Incremental Capital Cost	= \$ 30,000 - \$ 25,000 = \$ 5,000
Max. Amount Funded	= \$ 5,000

Capital Recovery	**=** $[(1 + 0.05)^5 (0.05)]/[(1 + 0.05)^5 – 1] = 0.23$
Annualized cost	=$ 5,000 * 0.23 = $ 1,150/year
Cost-Effectiveness	= ($ 1,150/year)/(0.40 tons/year) **= $ 2,875/ton**

The project meets the cost-effectiveness limit of $13,000 per ton NOx reduced and is eligible for an incentive amount of $5,000.

I. Reporting and Monitoring

The district has the authority to conduct periodic checks or solicit operating records from the applicant that has received Carl Moyer funds for new electric forklift projects. This is to ensure that the equipment is operated as stated in the program application. Forklift owners participating in the Carl Moyer Program are required to keep appropriate records throughout the life of the funded project. Records must contain, at a minimum, total hours operated, amount of electricity used, type and characteristic of charging equipment used, maintenance and repair information, and information pertaining to what was done with the ICE forklift that was replaced. All records must be retained and updated throughout the project life and made available at the request of the district. Districts could also conduct a scrapping program to ensure that the ICE forklifts being replaced are removed from the inventory.

Districts are also encouraged to closely review applications from applicants who own multiple facilities (i.e., own a chain of facilities) to determine that the applicant demonstrates a significant increase in electric forklift purchases at the new facility versus its existing facilities. Applicants with multiple facilities that are applying for funding at a new facility (additional outlet) would need to provide the district with adequate documentation on the history of forklift purchases for its California facilities. For example, Applicant X owns three outlets in California and is opening a fourth outlet. Applicant X is applying for Carl Moyer Program funding for new electric forklifts at that fourth outlet. Applicant X would need to provide its forklift purchasing history (i.e., the amount of electric forklifts versus ICE forklifts at each facility) to the district. In this example, the district reviews the historical purchasing data and determines that at facilities 1, 2 and 3 there are 80 percent electric forklifts and 20 percent ICE forklifts. Based on this data, the district would need to review the application for the new facility to determine that the applicant is demonstrating a significant increase in electric purchases over ICE purchases (i.e., 90% electric to 10 % ICE forklifts) at this facility versus its existing facilities. If the applicant demonstrates a significant increase in electric forklift purchases to ICE purchases over its other facilities, then the project could be funded, provided all other criteria are met.

ARB recommends that the local districts work with a third party, such as a local utility, on the monitoring program for forklifts with a lift capacity of 3,000 through 6,000 pounds. This monitoring program has additional requirements such as monitoring a certain percent of forklifts in this category to determine idling time. The selected percent would be approved by the district to be representative of the group of forklifts monitored. These items will also be monitored for a shorter duration. The other parameters such as hours of usage, amount of electricity used, type and characteristic of charging equipment, and maintenance and repair information will be collected for a six to twelve month period after purchase. Also, costs for maintenance, lease, and charging equipment (including installation) will also be monitored.

CHAPTER VIII.

AIRPORT GROUND SUPPORT EQUIPMENT

This document presents the project criteria under the Carl Moyer Program for airport ground support equipment (GSE). It also contains a brief overview of the NOx emission inventory, current emission standards, available control technology, potential incentive projects eligible for funding, and emission reduction calculation and cost-effectiveness calculation methodologies.

A. Introduction

Airport vehicles and ground support equipment are used to transport passengers as well as baggage and freight, to support maintenance and repair functions, and to provide power to various service functions. Vehicles and equipment at airports fall into two broad categories. Land-side vehicles and equipment are used on the passenger/entry side of the airport. Air-side vehicles are used principally (at least half of the time) on the tarmac. For the purposes of the Carl Moyer Program, the GSE category is restricted to air-side equipment. Land-side vehicles and equipment are included in the on and off-road vehicles and equipment project criteria previously adopted by ARB.

Airport GSE includes aircraft pushback tugs, baggage and cargo tugs, carts, forklifts and lifts, ground power units, air conditioning units, belt loaders, and other equipment. It also includes vehicles such as light duty trucks that are used for airplane maintenance and fueling on the air-side of airport operations. Airport GSE does not include aircraft engines.

Most GSE in California have internal combustion engines (ICE). Electric GSE has zero exhaust emissions and thus can greatly reduce NOx emissions. Electric GSE is commercially available from a number of manufacturers, and interest in the use of electric equipment is increasing. Currently, there are no federal or California regulations that require the use of electric GSE. Less than 10% of the GSE used at airports in California is estimated to be electric.

There are airports, however, with a very high percentage of electric GSE. For example, Denver International Airport was built within the last ten years, and was designed for all electric GSE. Also, Logan International Airport in Boston has made considerable progress in switching from ICE equipment to electric GSE equipment.

B. Ground Support Equipment and Emissions

GSE is used the moment an aircraft lands and until it takes off. GSE is used for tasks as diverse as towing, powering, and servicing. There is great diversity in the type of equipment used, as well as in the variety of engines that power GSE. The table below presents commonly used types of GSE and their estimated population in California. These estimates are from the ARB off-road emissions inventory. They do not include updated estimates for the South Coast Air Basin currently under development as part of the airport consultative process.

Table VIII-1
Airport GSE Population in California 1995

Equipment Type	Diesel	Gasoline	LPG/CNG	Statewide Total
Baggage Tug	440	646	89	1,175
Belt Loader	172	304	19	495
Forklifts, lifts & cargo loaders	197	319	214	730
Ground Power Unit	228	71	0	299
Aircraft Tug (narrow & wide body)	214	60	0	274
Airstart Unit	70	0	0	70
Air Conditioner	22	0	0	22
Deicer	0	29	0	29
Cart & Lavatory Cart	0	22	0	22
Fuel Trucks	23	56	26	105
Utility Trucks (lavatory, maintenance, water & service)	20	356	31	407
Bobtail	0	92	2	94
Other	17	160	17	194
TOTAL	1,403	2,115	398	3,916

- ***Baggage Tugs*** (or Tractors) transport luggage or cargo between aircraft and terminals.

- ***Belt Loaders*** are a self-propelled conveyer belt that moves baggage and cargo between the ground and the airport.

- ***Forklifts, Lifts, and Cargo Loaders*** include equipment for lifting and loading cargo.

- ***Ground Power Units (GPUs)*** provide electricity to parked aircraft.

- ***Aircraft Tugs*** (pushback tractors) tow aircraft in areas where aircraft can not use their own engines for motion. These are generally the areas between the taxiway and the terminal and between the terminal and the maintenance base.

- ***Air Start Units*** are trailer or truck-mounted compressors that provide air for starting up the aircraft's main engines.

- ***Air Conditioning Units*** are trailer or truck mounted compressors that deliver air through a hose to parked aircraft for cabin ventilation and engine cooling.

- ***Deicers*** are trailers equipped with tank, pump, hose, and spray gun to transport and spray deicing fluid on aircraft (to ensure that no ice builds up on body of plane or in turbines).

- ***Lavatory carts*** are used to service aircraft lavatories. Other types of carts can be used to transport equipment and personnel.

- ***Fuel Trucks, Utility Trucks, Maintenance, Water and Service Trucks*** are used on the air-side of the airport for many diverse tasks.

- ***Bobtail Tractors*** are on-road trucks modified to tow trailers and equipment

Airport GSE can be owned by airlines, airports, cargo handlers, mail and parcel companies or management companies. Most airlines own or maintain the GSE they use, or have full service leasing from equipment management companies. Airports usually own the buildings and other stationary infrastructure on site and lease them to the airlines. The installation and cost of improvements, including electric equipment and vehicle infrastructure, are usually subject to the approval of the airport's property management staff. Costs can either be borne by the airport or passed on to the airlines. There is also a growing trend for airports to own the ground power units and charge the airlines for the time of usage.

As indicated in Table VIII-1, there were an estimated 3,916 pieces of GSE operating in California in 1995. Table VIII-2 lists 1995 and 2010 estimated NOx emissions from airport GSE in the South Coast Air Basin and statewide.

Table VIII-2
Baseline NOx Emissions
Airport GSE

Location	Population	NOx Emissions (tons/day)	
		1995	2010
South Coast Air Basin	2,064	2.7	1.8
Statewide	3,916	5.0	3.2

C. Emissions Standards

Currently, there are no regulations that require the use of electric GSE at airports. However, the U.S EPA and ARB have adopted emission standards that are phased in over time and applicable to new (off-road) GSE equipment powered by internal combustion engines. Emission standards for GSE are contained in ARB and U.S EPA's emission standards for off-road equipment. Internal combustion engine GSE can either be powered by diesel engines (compression ignition engines) or by spark-ignited engines (which use gasoline, compressed natural gas, or propane fuel). There are separate emission standards for large spark-ignited engines and compression ignition engines.

1. Large Spark-Ignited Off-Road Engine Standards

Current model year large spark-ignited engines are not subject to either ARB or USEPA emission standards. ARB has approved standards for new large spark-ignited off road engines to be implemented beginning with the 2001 model year. These standards will apply to all new off-road spark-ignited engines greater than 25 horsepower, including off-road airport GSE.

The regulations include exhaust emission standards for nonmethane hydrocarbons (NMHC) and oxides of nitrogen combined, and for carbon monoxide. They also establish emission test procedures, test cycles, test fuel specifications, and emissions compliance requirements. Table VIII-3 contains the emission standards applicable to large spark-ignited engines that were approved by ARB.

Table VIII-3
Exhaust Emission Standards
Large Spark-ignited Engines

Year	Engine Size	NMHC + NOx (g/bhp-hr)	CO (g/bhp-hr)	Durability Period
2002 & later	<1.0 liter	9.0	410	1000 hours or 2 years
2001-2003 (Phase-in)	>1.0 liter	3.0	37	N/A
2004-2006 *	>1.0 liter	3.0	37	3500 hours or 5 years
2007 & later	>1.0 liter	3.0	37	5000 hours or 7 years

* *The standard for in-use compliance for engine families certified to the standards noted above shall be 4.0 gbhp-hr (5.4 g/kW-hr) hydrocarbon plus oxides of nitrogen and 50.0 g/bhp-hr (67 g/kW-hr) carbon monoxide for a useful life of 5000 hours or 7 years.*

2. Diesel Off-Road Engine Standards

ARB has adopted emission standards for off-road diesel cycle engines equal to or greater than 175 horsepower. The USEPA has adopted NOx emission standards for off-road diesel cycle engines at or above 50 horsepower. The combination of ARB and USEPA emission standards means that all of today's new off-road diesel cycle engines, including GSE, 50 horsepower and greater have to be certified to meet a NOx emission standard of 6.9 g/bhp-hr.

USEPA, ARB, and off-road diesel engine manufacturers have signed a Statement of Principles (SOP) that sets forth comprehensive future emission standards for compression ignition (diesel) off-road engines. USEPA has adopted regulations for off-road diesel equipment consistent with the emission levels contained in the SOP. The ARB intends to revise California's regulations for off-road equipment to harmonize with federal regulations. Table VIII-4 contains the applicable USEPA standards for off-road diesel engines.

Table VIII-4 USEPA Exhaust Emission Standards for Off-Road Diesel Engines								
	NOx and PM Emission Standards (g/bhp-hr)							
	1997/8		2003/2004		2007		2008	
Rated Power (horsepower)	**NOx**	**PM**	**NMHC +NOx**	**PM**	**NMHC + NOx**	**PM**	**NOx**	**PM**
50 ≤ hp < 100	6.9	--	5.6	0.30	5.6	0.30	3.5	0.30
100≤ hp < 175	6.9	--	4.9	0.30	3.0	0.22	3.0	0.22

3. Electric GSE Equipment

As discussed earlier there are no regulations requiring the use of electric GSE at airports. Measure M15 in the 1994 State Implementation Plan (SIP) called for USEPA to set new standards for aircraft engines. The SIP superseded USEPA's Federal Implementation Plan (FIP) which did call for electric GSE at airports. As an outgrowth of SIP/FIP activities, ARB, USEPA, the SCAQMD, the Air Transport Association, and other stakeholders in the South Coast Air Basin have been participating in a Public Consultative Process that include negotiations to develop approaches (besides aircraft emission standards) for reducing emissions from airport activities. The use of electric GSE is currently being considered for a MOU currently under negotiation for the five major airports in the South Coast Air Basin.

The outcome of these negotiations is expected to result in a Memorandum of Understanding signed by the stakeholders, agreeing to reduce emissions from airport GSE. The MOU will cover five airports in the South Coast: LAX, Ontario, Orange County, Burbank, and Long Beach. Because those five airports are covered under the current MOU negotiation process, they would not be eligible for funding under the Carl Moyer Program.

D. Control Strategies

A cost-effective way to reduce emissions is to replace GSE powered by an internal combustion engine with electric equipment. Electric equipment has no exhaust emissions and replacing equipment powered by ICE engines with electric equipment will reduce NOx emissions. Electric GSE is commercially available for a number of equipment types, including belt loaders, baggage tractors, aircraft tugs, lifts, and GPU's. Several airlines and airports have conducted electric GSE demonstration programs and fleet conversion programs. Much of the experience to date with electric equipment has been quite positive. In addition to air quality benefits, users have found that electric equipment is more "task specific" than ICE equipment. Electric equipment often includes more ergonomic features and users find that it "rides better" than equivalent diesel equipment. However, the higher capital cost of electric equipment has prevented its widespread use to date. A detailed discussion of control strategies is included in the report: "*Assessment of Airport Ground Support Equipment Using Electric Power or Low-Emitting Fuels (Final Report),*" prepared for the Air Resources Board by Arcadis Geraghty & Miller, July 20, 1999.

The Carl Moyer Program will fund the replacement of ICE GSE with comparable electric equipment. The most promising categories are those where electric equipment has been used and demonstrated, and is readily available from commercial vendors. This includes electric baggage tugs, belt loaders, and aircraft tugs. These equipment categories also represent a significant portion of the statewide GSE population, and also have some of the highest average annual hours of usage. Replacing these ICE equipment types with comparable electric equipment would reduce NOx emissions. Therefore, the Carl Moyer Program guidelines have been designed to target these categories. Other promising projects include lifts and cargo loaders. Deciers, carts, lavatory carts and airstart units each represent a much smaller part of the GSE equipment inventory (less than 100 units each statewide). Fuel, utility, water, and service trucks are not covered under the airport GSE guidelines, but can qualify under the on-road category, provided they meet on-road vehicle project criteria.

E. General Project Criteria

The primary focus of the Carl Moyer Program is to achieve emission reductions from off-road engines and equipment operating in California as early and as cost-effectively as possible. The project criteria are designed to ensure that the emission reductions expected through the deployment of electric GSE funded under the program are real and quantifiable. A project must meet a cost-effectiveness criterion of $13,000 per ton of NOx reduced, must operate for at least five years from the time it is first put into operation, and at least 75 percent of the hours of operation must occur in California.

F. Airport GSE Project Criteria

Airport GSE projects must meet the general project criteria, and the specific airport GSE project criteria provided below. In an effort to normalize the project life for GSE projects, ARB staff revised the criteria to include a maximum allowable project life for GSE projects.

- ICE equipment must be replaced with new electric equipment.

- Eligible equipment includes the following types of equipment: belt loaders, baggage tugs or tractors, forklifts, lifts, cargo loaders, ground power units, or aircraft tugs. Other GSE equipment will be evaluated on a case-by-case basis.

- Equipment must be purchased for use at a commercial (passenger) airport in California.

- Equipment purchased for use at a military airport will be considered on a case-by-case basis. The equipment must not be covered by any existing regulations or permit requirements, and the emission reductions must be surplus to any credit banking programs.

- Equipment must be purchased by the business or organization that will be operating the equipment. This includes airports as well as passenger airline companies.

- Purchases by airline service companies or ground handlers are eligible if they provide documentation (such as written contracts or other binding agreements) specifying that they will operate the equipment at a passenger airport not excluded under the Carl Moyer Program for a minimum five year period.

- The ICE equipment which is being replaced must have an engine rated at 50 horsepower or greater (which is equivalent to an electric motor 37 kilowatts or greater).

- NOx reductions obtained through this program must not be required by any regulation, memoranda of understanding/agreement, air quality permit requirement, California Environmental Quality Act (CEQA) or other offset agreement, or any other legally binding agreement.

- Equipment purchased for use at LAX, Ontario, Orange County, Burbank, or Long Beach airports is excluded from the Carl Moyer Program.

- Leased or rented equipment is excluded from the Carl Moyer Program, as is used equipment.

- The acceptable project life for calculating emission benefits from GSE projects is 5 years.

G. Sample Application

In order to qualify for incentive funds, districts provide applications and solicit bids for reduced-emission projects from GSE equipment operators. A sample application form is included in Appendix I and the minimum project information is listed in Table VIII-5 below.

Table VIII–5 Minimum Application Information GSE Projects	
1. Air District: 2. Applicant Demographics Company Name: Business Type: Mailing Address: Location Address: Contact Number: Equipment Operator: (airport, airline, equipment management company, other) 3. Project Description Project Name: Engine Function: VIN or Serial Number: Airport where equipment operated: Equipment Function: (replacement for an existing equipment, fleet expansion, other) 4. Application: (Repower, Retrofit or New) 5. Annual Hours of Operation: 6. Percent Operated in California: 7. Project Life (years): 8. Existing ICE Equipment Being Replaced (if an existing business) Horsepower Rating: Manufacturer: Model: Year: Fuel Type	9. New Equipment Information Horsepower Rating: Make: Model: Year: Manufacturer Type of New Equipment purchases Number of New Equipment purchased: 10. NOX Emissions Reductions Baseline NOx Emissions Factor (g/bhp-hr): NOx Conversion Factor Used: Reduced NOx Emissions Factor (g/bhp-hr): Estimated Annual NOx Emissions Reductions: Estimated Lifetime NOx Emissions Reductions: 11. Cost of New Equipment (including 1 battery pack) 12. Cost ($) of the Base Engine: 13. Cost ($) of Certified LEV Engine: 14. PM Emissions Reductions Baseline PM Emissions Factor (g/bhp-hr): PM Conversion Factor Used: Reduced PM Emissions Factor (g/bhp-hr): Estimated Annual PM Emissions Reductions: Estimated Lifetime PM Emissions Reductions: 15. District Incentive Grant Requested:

H. Emission Reduction and Cost-Effectiveness

1. Emission Reduction Calculation

The emission reduction benefit will be calculated for NOx emissions only and will be determined using the annual hours of operation. Annual NOx emission reductions are determined by multiplying the difference in the NOx emission levels of electric and ICE equipment, the engine load factor, and the hours the engine is expected to operate per year.

The load factor is an indication of the amount of work done, on average, by an engine in a particular application, given as a fraction of the rated horsepower of that engine. If the actual load factor is known for an engine it should be used in calculating emission reductions. If the actual load factor is not known, the default value contained in Table VIII-6 will be used.

Another variable in determining emission reductions is the number of hours the equipment operates. If actual hours of equipment operation are not available, the default values given in Table VIII-6 should be used to calculate emission reductions. ARB staff revised the default values to reflect the most recently adopted version of the OFFROAD model. Baseline NOx emissions for ICE equipment are provided in Table VIII-7. All information in Table VIII-6 is taken from ARB's off-road emission inventory.

Table 6
Default Load Factors and Annual Operating Hours

Equipment	Horsepower	Load Factor	Annual Hours
Belt Loader	51-120 (*60)**	0.50	810
Baggage Tug	130-175 (*100)*	0.55	876
Cargo Loaders	51-120 *(70)*	0.50	719
A/C Tugs wide body	250-500 *(500)*	0.80	515
A/C Tugs narrow body	121-175 *(130)*	0.80	551
Lifts	51-120 *(100)*	0.50	376
Ground Power Units	120-175 (*150)*	0.75	796

Table VIII-7
Default Baseline Emission Factors for GSE Equipment

Horsepower Range	Fuel Type	Baseline NOx Emission Rate (grams/bhp-hr)
>50	Propane	10.5
51-120	Gasoline	11.8
121-175	Gasoline	12.9
51-300	Diesel	6.9

2. Cost-Effectiveness Calculation

The portion of the cost for a GSE project to be funded through the Carl Moyer Program is the difference between the total cost of purchasing new electric equipment and the cost of buying “conventional” replacement equipment. Only the amount of money provided by the Carl Moyer program and any local district match funds can be used in the cost-effectiveness calculations. The one-time incentive grant amount is to be amortized over the expected project life (at least five years) with a discount rate of five percent. The amortization formula (given below) yields a capital recovery factor, when multiplied with the initial capital cost, gives the annual cost of a project over its expected lifetime.

Capital Recovery Factor (CRF) = $[(1 + i)^n (i)] / [(1 + i)^n - 1]$

Where, i = discount rate (5 percent)
n = project life (at least five years)

The discount rate of five percent reflects the opportunity cost of public funds for the Carl Moyer Program. This is the level of earning that could be reasonably expected by investing state funds in various financial instruments, such as U.S. Treasury securities. Cost-effectiveness is determined by dividing the annualized cost by the annual NOx emission reductions. Example calculations for GSE projects are provided below.

3. Examples

For the purposes of explaining the emission reduction and the cost effectiveness calculations from a particular GSE project, two examples are presented below. The first example describes the calculations based on replacing four diesel baggage tugs with four electric baggage tugs, and the second example shows calculation for the replacement of a gasoline belt loader with an electric belt loader.

Example 1 – Calculations for replacement of a diesel baggage tug based on hours of operation.

A passenger airline in Sacramento applies for a Carl Moyer Program grant for the purchase of four new electric baggage tugs to replace four diesel baggage tugs currently in the fleet. The airline has decided to purchase the electric baggage tugs instead of purchasing new diesel baggage tugs certified to a 6.9 g/bhp-hr NOx standard. The cost of a new electric baggage tug is $24,000 (each), or whereas the cost to buy a new diesel baggage tug is $19,000 (each). The new baggage tugs each will operate 876 hours annually (each) and will operate 100 percent of the time in California.

<u>Emission Reduction Calculation</u>

Baseline NOx Emissions:	6.9 g/bhp-hr (new diesel baggage tug)
Reduced NOx Emissions:	0 g/bhp-hr (new electric baggage tug)
Horsepower Rating:	100 hp
Load Factor:	0.55
Annual Operating Hours:	876 hours
% Operated in CA:	100%
Converts grams to tons:	ton/907,200 g

Baseline Engine
6.9 g/bhp-hr *100 hp * 0.55 *876 hrs/yr * 4 baggage tugs * 100% * ton/907,200 g = 1.46 tons/yr

Reduced Engine
0.0 g/bhp-hr *100 hp * 0.55 *876 hrs/yr * 4 baggage tugs * 100% * ton/907,200 g = 0.0 tons/yr

1.46 tons/year – 0.0 tons/year = **1.46 tons/year NOx emissions reduced**

Cost-Effectiveness Calculations

The annualized cost is based on the portion of incremental project costs funded by the Carl Moyer Program, the expected life of the project (5 years at a minimum), and the interest rate (5 percent) used to amortize the project cost over the project life. The incremental capital cost to the equipment owner for this purchase and the maximum amount that could be funded through the Carl Moyer Program fund are determined as follows:

Total cost of new electric baggage tug	**=** \$ 24,000 x 4 = \$ 96,000
Cost of new diesel baggage tug	**=** \$ 19,000 x 4 = \$ 76,000
Incremental Capital Cost	**=** \$ 96,000 - \$ 76,000 = \$ 20,000
Max. Amount Funded	= \$ 20,000
Capital Recovery	**=** $[(1 + 0.05)^5 (0.05)]/[(1 + 0.05)^5 – 1] = 0.23$
Annualized cost	= \$ 20,000 * 0.23 = \$ 4,600/year
Cost-Effectiveness	**=** (\$ 4,600/year)/(1.46 tons/year) **= \$ 3,151/ton**

The project meets the cost-effectiveness limit of \$13,000 per ton NOx reduced and is eligible for an incentive amount of \$20,000.

Example 2– Calculations for replacement of a diesel belt loader based on hours of operation.

An airline company that operates at the Fresno airport applies for a Carl Moyer Program grant for the purchase of a new electric belt loader to replace a diesel belt loader in their existing fleet. The new electric belt loader will be used for five years at the Fresno airport. The airport has decided to purchase a new electric belt loader instead of purchasing a new diesel belt loader. The cost of the new electric belt loader is \$30,000, whereas the cost to buy a new gasoline belt loader is \$27,000. The new belt loader will operate 810 hours annually and will operate 100 percent of the time in California.

Emission Reduction Calculation

Baseline NOx Emissions:	6.9 g/bhp-hr (new diesel belt loader)
Reduced NOx Emissions:	0 g/bhp-hr (new electric belt loader)
Rated Horsepower:	60 hp
Annual Operating Hours:	810 hours
Load Factor:	0.55
% Operated in CA:	100%
Converts grams to tons:	ton/907,200 g

Baseline Engine
6.9 g/bhp-hr * 60 hp * 0.55 * 810 hours/year * 100% * ton/907,200 g = 0.20 tons/year

Reduced Engine
0.0 g/bhp-hr * 60 hp * 0.55 * 810 hours/year * 100% * ton/907,200 g = 0.0 tons/year

0.20 tons/year – 0.0 tons/year = **0.20 tons/year of NOx emissions reduced**

Cost-Effectiveness Calculations

The annualized cost is based on the portion of incremental project costs funded by the Carl Moyer Program, the expected life of the project (5 years at a minimum), and the interest rate (5 percent) used to amortize the project cost over the project life. The incremental capital cost to the equipment owner for this purchase and the maximum amount that could be funded through the Carl Moyer Program fund are determined as follows:

Total cost of new electric belt loader	**=** $ 30,000
Incremental Capital Cost	**=** $ 30,000 - $ 27,000 = $ 3,000
Max. Amount Funded	= $ 3,000
Capital Recovery	**=** $[(1 + 0.05)^5 (0.05)]/[(1 + 0.05)^5 – 1] = 0.23$
Annualized cost	= $ 3,000 * 0.23 = $ 690/year
Cost-Effectiveness	**=** ($ 690/year)/(0.24 tons/year) **= $ 2,875/ton**

The project meets the cost-effectiveness limit of $13,000 per ton NOx reduced and is eligible for an incentive amount of $3,000.

I. Reporting and Monitoring

The district has the authority to conduct periodic checks or solicit operating records from the applicant that has received Carl Moyer funds for new electric GSE projects. This is to ensure that the equipment is operated as stated in the GSE program application. Those participating in the Carl Moyer Program are required to keep appropriate records during the life of the project funded. Records must contain, at a minimum, total hours operated, amount of electricity used, and maintenance and repair information. Records must be retained and updated throughout the project life and made available at the request of the district.

CHAPTER IX.

PARTICULATE MATTER EMISSION REDUCTION REQUIREMENTS AND GOALS

This chapter describes the Particulate Matter (PM) baseline levels and calculation methodology. This chapter also contains a brief overview of available control technologies, the Advisory Board's established PM target and requirement, PM emissions reduction calculations, and examples for calculating PM emission reductions.

A. Introduction

Diesel PM is a serious public health concern. Diesel PM, like ozone, has been linked to a range of serious health problems including an increase in respiratory disease, lung damage, cancer, and premature death. Fine diesel particles are deposited deep in the lungs and can result in increased hospital admissions and emergency room visits; increased respiratory symptoms and disease; decreased lung function, particularly in children and individuals with asthma; alterations in lung tissue and respiratory tract defense mechanisms; and premature death. On August 27, 1998, after extensive scientific review and public hearing, the Air Resources Board (ARB) formally identified particulate emissions from diesel-fueled engines as a toxic air contaminant.

The Carl Moyer Program was originally designed to help California meet the NOx emission reductions in measure M4 in the 1994 SIP. Although the focus of the program is on NOx reductions, some of the technologies, such as electric motors and alternative fueled engines, funded under this program also reduce PM. Even without specific requirements to reduce PM, the Carl Moyer Program has achieved approximately 100 pounds per day of PM reductions from projects funded in its first year. Based on recent information regarding the risks associated with PM, however, it has become more critical to include PM reductions into the Carl Moyer Program.

1. Advisory Board Recommendations

Health and Safety Code, Section 44297, created the thirteen-member Advisory Board designated with the responsibility of reviewing the Carl Moyer Program and providing the Legislature and the Governor with a report containing recommendations for the Carl Moyer Program beyond the first year. The Advisory Board released their report to the Governor and Legislature on March 31, 2000. In that report, the Advisory Board recognized that diesel PM is a serious public health concern and PM reductions are necessary throughout California. The Advisory Board established a PM reduction target for the statewide program and a PM reduction requirement for areas that are designated as non-attainment for the federal PM standard. As a result of the PM criteria recommended by the Advisory Board, ARB has incorporated new PM default baseline levels and calculation methodologies for calculating PM emissions.

2. Emission Inventory

Statewide NOx and particulate matter less than 10 microns (PM_{10}) emissions from selected categories of heavy-duty engines are shown in Table IX-1. PM emissions statewide from mobile sources are about 120 tons per day (1996 inventory). Heavy-duty mobile source engines account for about 60 percent of PM mobile source emissions statewide. Light and medium-duty vehicles account for about 30 percent. Currently two districts, San Joaquin Valley and South Coast exceed federal PM ambient air quality standards. Most districts do not attain California's most stringent state PM standards, leaving millions of California's exposed to dangerous amounts of PM on a daily basis.

Table IX-1
Statewide Emissions from Selected Heavy-Duty Engine Categories

Source Category	Current PM	2010 PM_{10}
On-Road Heavy-Duty Vehicle [a]	37	14
Off-Road Equipment [b]	22	26
Locomotive	3	3
Marine	10	12
Total	72	55

a) Emissions from gasoline and diesel trucks and buses. Emissions based on EMFAC7G model, corrected to account for 2004 standards and off-cycle emissions.

b) 1996 emissions from off-road equipment, including equipment less than 50 horsepower. The off-road equipment emissions inventory is currently being revised.1996 emissions.

3. Emission Standards

The model year PM emission factors listed in Tables IX-2, IX-3, and IX-4 represent the EMFAC2000 zero mile emission factors of diesel-powered medium heavy-duty vehicles, heavy heavy-duty vehicles, and urban buses, respectively. School buses and neighborhood refuse trucks should use the emission factors and conversion factors according to their GVWR. For alternative-fueled urban transit buses, however, existing in-use test data shows that PM in-use emissions are 30-50 percent lower for a natural gas bus certified to the proposed 0.03 g/bhp-hr PM standard than for a diesel bus engine certified to the proposed 0.01 g/bhp-hr PM standard. So, alternative-fueled urban transit buses should use 0.025 g/mile PM emission factor.

Table IX-5 provides model year emission factors from the adopted OFFROAD model by horsepower group. These off-road emission factors would be used for stationary agricultural irrigation pumps and harbor vessels with medium speed diesel engines. Table IV-2 lists the PM emission factors for locomotives based on USEPA standards and Tier 0 should be used for uncontrolled engines.

Table IX-2 PM Emission factors for Medium Heavy-Duty Vehicles 14,001 – 33,000 lbs GVWR	
Model Year	**g/mile**
Pre - 1984	1.1
1984 - 1986	1.0
1987 - 1990	0.7
1991 - 1993	0.4
1994 - 1997	0.3
1998 - 2002	0.2
2003 +	0.3

Table IX-3 PM Emission factors for Heavy Heavy-Duty Vehicles 33,000 + lbs GVWR	
Model Year	**g/mile**
Pre - 1975	2.0
1975 - 1983	1.8
1984 - 1986	1.2
1987 - 1990	0.8
1991 - 1993	0.5
1994 - 1998	0.3
1999 - 2002	0.2
2003 +	0.3

Table IX-4 PM Emission factors for Urban Buses	
Model Year	**g/mile**
Pre - 1987	1.3
1987 - 1990	1.2
1991 - 1993	1.1
1994 - 1995	1.4
1996 - 1998	1.7
1999 - 2002	0.6
2003 - 2005	0.1

Table IX-5 PM Emission factors for Heavy-Duty Off-Road Diesel Engines		
Horsepower	**Model Year**	**g/bhp-hr**
50 - 120	Pre - 1988	0.84
	1988 - 2003	0.69
	2004	0.39
	2005	0.29
121 - 175	Pre - 1970	0.77
	1970 - 1971	0.66
	1972 - 1987	0.55
	1988 - 2002	0.38
	2003	0.24
	2004	0.19
176 - 250	Pre - 1970	0.77
	1970 - 1971	0.66
	1972 - 1987	0.55
	1988 - 2002	0.38
	2003	0.24
	2004	0.19
	2005	0.16
251 - 500	Pre - 1970	0.74
	1970 - 1971	0.63
	1972 - 1987	0.53
	1988 - 1995	0.38
	1996 - 2000	0.15
	2001	0.12
	2002 - 2005	0.11
501 - 750	Pre - 1970	0.74
	1970 - 1971	0.63
	1972 - 1987	0.53
	1988 - 1995	0.38
	1996 - 2001	0.15
	2002	0.12
	2003 - 2005	0.11
751+	Pre - 1970	0.74
	1970 - 1971	0.63
	1972 - 1987	0.53
	1988 - 1999	0.38
	2000 - 2005	0.15

4. Control Technologies

This section discusses current PM retrofit control technologies. A retrofit involves a hardware modification to an existing engine to reduce its emissions from the standards to which it was originally certified.

A variety of catalysts and filters (traps) have been developed over the last five years. PM catalysts have a control efficiency of around 30% while filters can achieve over 90% PM reduction. These control efficiencies would increase if used in conjunction with very low sulfur fuel.

PM catalysts have the advantage of being devices that can be added fairly easily but are not as effective as filters. Filters, however, require some means of regeneration or cleaning off the collected PM. The most effective way is to burn it. Failure to burn off PM in time can plug the filter and stop the engine, while burning too much at one-time can overheat and damage the filter. In most applications, the diesel exhaust temperature is not hot enough to start a filter's regeneration cycle.

One of the technologies that manufacturers express as the solution to the diesel PM problem is a catalyst-based diesel particulate filter (DPF). This is a filter that burns off the particulate using a catalyst to induce ignition. The catalyst material can either be directly incorporated into the filter system, or can be added to the fuel as a fuel-borne catalyst. In several European countries, catalyst-based DPFs have been installed on more than 6,500 heavy-duty vehicles. In the United States, the application of catalyst-based DPFs is less prevalent, but several demonstration projects are underway. In California, diesel fueled school buses and tanker trucks have been retrofitted with catalyzed DPFs as part of a program to evaluate the effectiveness of a refiner's low-sulfur diesel formulation.

B. PM Target and Requirement

Through a public process, the Advisory Board established the following PM reduction target and requirement:

- A 25 percent PM emissions reduction target for all districts on a statewide program-basis, except for Serious PM nonattainment areas.

- A 25 percent PM emissions reduction requirement for districts designated as Serious PM nonattainment. Non-attainment districts for the federal PM standard <u>must</u> reduce PM emissions by 25 percent, district-wide (on a program basis, instead of a project-by-project basis). Currently, SJVAPCD and SCAQMD are the only two districts affected by the proposed requirement.

C. Emission Reductions

The program cost-effectiveness will continue to be calculated based on the NOx reductions alone. PM emission reductions would be calculated similar to the NOx emission reductions. For example if a project uses its annual miles traveled to determine its NOx emissions reductions, then it must also use annual miles traveled as the basis for determining PM emission reductions. It is important to understand, however, that baseline uncontrolled PM emission levels and controlled emission levels for PM emissions will differ from NOx emission level. These factors are listed in tables

IX-2 through IX-5 above. Overall program reductions will be considered when determining whether or not the 25 percent target/requirement has been met.

1. Emission Reduction Calculations

In order to incorporate the Advisory Board's PM criteria into the Carl Moyer Program, ARB is providing PM emission factors to calculate PM emission reductions from the program. PM emission reductions would be calculated in the same manner as the NOx emission reductions. Depending on the methodology the guidelines specifies for a particular project; the same criteria would apply when calculating PM emissions. ARB staff will determine overall statewide and district compliance with the PM reduction goals and requirements. If the program falls short, ARB staff will propose modifications to the program to achieve the necessary reductions.

For simplification purposes, PM emission reductions will be expressed in pounds reduced. The project life is provided under the project criteria in each project category chapter.

2. Examples

Example 1: Diesel-to-Diesel On-Road Vehicle Repower (Calculations Based on Annual Miles Traveled). A line haul trucking company proposes to repower a model year 1986 truck with a model year 1990 diesel engine. The truck travels 60,000 miles a year and has a GVWR of 35,000 pounds. The applicant used the vehicle's annual miles traveled to determine NOx emissions reductions, and hence, will also use annual miles traveled to calculate PM emissions reductions.

Baseline PM Emissions:	1.2 g/mile
Reduced PM Emissions:	0.8 g/mile
Annual Miles Traveled:	60,000 miles
% Operated in CA:	100%
Convert grams to pounds:	lbs/454 g

Baseline Engine: 1.2 g/mile * 60,000 miles * 100% * lbs/454 g = 159 lbs/year

Reduced Engine: 0.8 g/mile * 60,000 miles * 100% * lbs/454 g = 106 lbs/year

Estimated Annual PM Reductions

159 lbs/year - 106 lbs/year = **53 lbs/year PM emissions reduced**

Example 2: On-Road Diesel-to-CNG Repower (Calculations Based on Annual Miles Traveled). Consider a transit company faced with the opportunity of replacing a fleet of diesel-fueled buses with CNG fueled buses. The applicant opts to use the annual miles traveled to determine its NOx emissions reductions. Hence, the vehicle's annual miles traveled will be used to determine the PM emissions reduced. The current heavy-duty diesel engine dates to 1991.

Baseline PM Emissions: 1.1 g/mile
Reduced PM Emissions: 0.025 g/mile
% Operated in CA: 100%
Annual Miles Traveled: 70,000 miles
Convert grams to pounds: lbs/454 g

Baseline Engine: 1.1 g/mile * 70,000 miles * 100% * lbs/454 g = 170 lbs/year

Reduced Engine: 0.025 g/mile * 70,000 miles * 100% * lbs/454 g = 4 lbs/year

Estimated Annual PM Reductions

170 lbs/year – 4 lbs/year = **166 lbs/year PM emissions reduced**

Example 3: Locomotive Diesel to Diesel Repower (Calculations Based on Annual Fuel Consumption). A railroad operator, participating in the Carl Moyer Program, repowers the uncontrolled diesel engine of a switcher with a lower emitting Tier 1 engine. The applicant used the annual fuel consumption of 50,000 gallons/year to determine NOx emission reductions, and so will use annual fuel consumption to calculate PM reductions. This locomotive operates 100% of its activity in California.

Baseline PM Emissions: 0.72 g/bhp-hr
Reduced PM Emissions: 0.52 g/bhp-hr
Energy Consumption Factor: 20.8 bhp-hr/gal
Annual Fuel Consumption: 50,000 gal/year
% Operated in California: 100%
Convert grams to pounds: lbs/454 grams

Baseline Engine: 0.72 g/bhp-hr * 20.8 bhp-hr/gal * 50,000 gal/yr * 100% * lbs/454 g = 1649 lbs/yr

Reduced Engine: 0.52 g/bhp-hr * 20.5 bhp-hr/gal * 50,000 gal/yr * 100% * lbs/454 g = 1191 lbs/yr

Estimated Annual PM Reductions

1649 lbs/year - 1191 lbs/year = **458 lbs/year PM emissions reduced**

Example 4: Off-road Diesel-to-Diesel Repower (Calculations Based on Hours of Operation). A farmer applies for a Carl Moyer Program grant to repower a grape harvester's uncontrolled 1969 diesel engine with at lower NOx and PM emitting model year 2000 diesel engine. Both engines are rated at 195 horsepower. If the farmer used 700 annual hours of operation to determine the NOx emissions reductions, then she must also base her PM emission reduction calculation on hours of operation. The project life of the grape harvester is 10 years and it operates 100% in California.

Baseline PM Emissions: 0.77 g/bhp-hr
Reduced PM Emissions: 0.38 g/bhp-hr

Rated Horsepower: 195 hp
Load Factor: 0.65
Annual Operating Hours: 700 hrs
% Operated in California: 100%
Convert grams to pounds: lbs/454 g

Baseline Engine
0.77 g/bhp-hr * 195 hp * 0.65 700 hrs/year * 100% * lbs/454 g = 150 lbs/year

Reduced Engine
0.38 g/bhp-hr * 195 hp *0.65 * 700 hrs/year * 100% * lbs/454 g = 74 lbs/year

Estimated Annual PM Reductions

150 lbs/year - 74 lbs/year = **76 lbs/year PM emissions reduced**

* NOTE: For areas designated serious nonattainment for PM, ARB will calculate the PM emission reductions on a program-wide basis, not a project-to-project basis. Consider the four previous examples as constituting a local district program. These projects yield a total of 753 lbs/year of PM reductions and 2128 lbs/year of baseline PM emissions. Such a program represents a 35 percent PM emission reduction and meets the 25 percent PM emission reduction requirement. For areas designated attainment for PM emissions, ARB will calculate the PM emissions reductions statewide and the 25 percent PM reduction is a target.

D. Reporting and Monitoring

Each project category chapter contains monitoring and reporting instructions. PM reporting requirements are included in the minimum information application table of each project category chapter.

CHAPTER X.

AUXILIARY POWER UNITS FOR REDUCING IDLING EMISSIONS FROM HEAVY-DUTY VEHICLES

This chapter presents the project criteria for auxiliary power units (APUs) that are installed in an on-road heavy-duty vehicle to reduce the vehicle's idling emissions under the Carl Moyer Program. It also contains a brief overview of the engine idling practice of operators of heavy-duty vehicles, NOx emission inventory, available control technology, potential projects eligible for funding, and emission reduction and cost-effectiveness calculation methodologies.

A. Introduction

Heavy-duty vehicles are often employed in line-haul service carrying goods across the state and throughout the nation. The majority of all heavy-duty vehicles are powered by diesel engines. Heavy-duty vehicles employed in line-haul service are typically greater than 33,000 pounds GVWR and are grouped under a “class 8” truck classification. These vehicles often accrue very high annual mileage. It is not uncommon for a line-haul truck to accrue 100,000 miles, or more, annually. At the same time, however, the engines in these vehicles also operate at idle conditions for a significant amount of time annually, unnecessarily consuming fuel and increasing emissions.

Truck idling practices vary among different fleets, operators, and geographical locations. There are various reasons why line-haul truck operators idle their engines. Two main reasons are to keep the engine and fuel warm, especially in very cold weather, and to heat or cool the cab/sleeper compartment. Since heavy-duty diesel engines do not operate at optimum efficiency at idle conditions, extended engine idling results in increased emissions and fuel consumption. Although technologies for reducing idling emissions from heavy-duty trucks are commercially available, relatively high initial costs have prevented these idling reduction strategies from being more widely utilized.

The Carl Moyer Program can provide incentives to reduce emissions from truck idling by encouraging the purchase and installation of alternative idling reduction technologies. These technologies can not only reduce idling emissions from heavy-duty trucks, but can also result in fuel savings and reduced maintenance costs to truck operators.

1. Emission Inventory

According to EMFAC2000, idling emissions from heavy-duty diesel trucks account for about 21 tpd of NOx, or about three percent of the total NOx emissions from this sector of vehicles in California. This inventory may underestimate the actual amount of emissions attributable to truck idling since it only accounts for certain defined events of idling that do not comprise the entire envelope of actual idling practices. Idling emissions from individual trucks are still significant, however, since the idling emission rate for heavy-duty diesel trucks is quite large. For example, a single heavy-duty truck that idles an average of about four hours per day would emit about one-half ton of NOx emissions annually, just from idling.

2. Emission Standards

Aside from the overall emission standards applicable to heavy-duty diesel engines, there are no specific emissions standards to control heavy-duty engine idling operation. Some local government and municipalities, however, are beginning to consider ordinances restricting the length of engine idling. Since there is no existing emission standards to serve as baseline emission level for the purpose of calculating emission benefits of an idling reduction technology, the EMFAC2000 idling emission rate for heavy-duty diesel trucks shall be used as the idling emission baseline. Currently, some commercially available technology for reducing truck idling emissions make use of a small off-road engine as the power unit for supplying heating and cooling needs to the truck/cab and, in some cases, electricity to power the truck accessory loads. In these cases, the new emission level would be based on the emission standards that these small off-road engines are certified to. Table X-1 lists the existing and future emission standards for small off-road diesel engines that are likely to be employed in APU idling reduction devices.

Table X-1
Emission Standards for 2000 -2004 Model Year
Off-Road Compression Ignition Engines
0 – 19 kW (0 - 25.5 hp)

Pollutants	Power Rating < 8 kW (10.7 hp)	Power Rating 8 < kW<19 (10.7<hp<25.5)
HC + NOx	10.5 g/kW-hr (7.8 g/bhp-hr)	9.5 g/kW-hr (7.1 g/bhp-hr)
PM	1.0 g/kW-hr (0.75 g/bhp-hr)	0.8 g/kW-hr (0.6 g/bhp-hr)

3. Control Technologies

Several technologies are commercially available that could be employed to reduce idling emissions from heavy-duty trucks. These technologies are discussed below.

a. <u>Auxiliary Power Units</u>

Auxiliary power units (APUs) are self-contained power generating devices, typically packaged with a small internal combustion engine, of 20 horsepower or less, that could be coupled with a generator and heat exchanger to generate electricity and heat. APUs are usually installed on the truck chassis outside the truck cab to provide power for the truck’s accessory loads and to keep the engine warm when the truck is parked. This would allow the truck operator to refrain from idling the truck main engine for a significant portion of time. The extent of labor involved in the installation of an APU on the truck is dependent on the configuration of the truck's engine and chassis and the plumbing of its heating/cooling system. Heating and cooling of the cab compartment are accomplished through either dedicated equipment supplied with the APU or through the truck's existing heating and cooling system. APUs are commercially available and would be able to meet most of the power needs of truck operators.

b. Direct-Fired Heaters

Direct-fired heaters for truck heating applications are devices that use the combustion heat of a small internal combustion engine to provide heat directly to the truck's cab/sleeper area through the use of a small heat exchanger. Because it is designed to provide heat directly from a combustion flame, the heating efficiency of these units is much higher than that obtained through the truck's engine due to reduced mechanical losses and fuel consumption. Two primary limitations of direct-fired heaters for this application are that they cannot provide cooling and that they draw on the truck's battery power during operation. Technologies for overcoming the latter limitation are evolving, but this technology has not gained widespread commercial acceptance.

c. Thermal Storage/Direct-Fired Heaters

Another technology that could provide both heating and cooling for the cab/sleeper areas is a thermal storage system. This technology uses the heat of transformation associated with material phase change to provide heating and cooling, respectively, to the cab/sleeper area. This technology currently has several drawbacks: (1) it cannot provide heat to the engine to keep it warm unless a direct-fired heater is also incorporated with the thermal storage system; (2) it cannot provide cooling needs at night unless the truck's air conditioner was used in the daytime; and (3) it uses the truck's battery power.

d. Truck Stop Electrification

Another strategy for reducing truck idling is electrification of truck stops or truck rest areas where trucks are parked overnight. This strategy requires the installation of charging infrastructure at truck stops and rest areas and requires the retrofit of trucks with various components, such as engine block heater, fuel heater, electric heater for cab/sleeper areas, etc. Enabling technologies for an electrification strategy are commercially available.

B. Project Criteria

The project criteria for eligible idling reduction strategies for heavy-duty vehicles provide districts and fleet operators with the minimum qualifications that must be met for a project to qualify for funding. The criteria are developed specifically for APUs that will be installed on a heavy-duty truck to reduce the truck's idling emissions. Idling reduction strategies other than through the use of an APU could be evaluated on a case-by-case basis. Criteria for other idling reduction strategies may be developed in the future depending on the market demand and availability for those specific technologies.

APUs would provide a cost-effective means to reduce idling emissions from heavy-duty diesel trucks. However, because of the attractive life-cycle cost of this technology, Moyer funds should not be used to pay for the full cost of an APU. APUs are expected to pay for themselves in a few years, after which these units will provide a positive revenue stream to the truck owners/operators in the form of fuel savings. The payback period and the amount of fuel savings would depend on the total cost of the units, actual idling hours, fuel prices, and maintenance costs. Therefore, a maximum amount of $1,500 per diesel APU, and $3,000 per alternative fuel, electric motor, is allowed in this project category. This amount is intended to help pay for the installation cost of the APU. The amount that would be funded for any individual project would depend on the actual installation cost, but in no case could exceed $1,500 for a diesel APU and $3,000 for an alternative fuel or fuel cell APU.

The main criteria for selecting a project are the amount of emission reductions, cost-effectiveness, and ability for the project to be completed within the timeframe of the program. These criteria also provide districts and vehicle operators with calculations that must be used for determining emission reductions and cost effectiveness resulting from idling emission reduction projects.

- Eligible projects must provide at least 15 percent NOx emission benefit compared to baseline idling NOx emissions;

- NOx reductions obtained through this program must not be required by any existing regulations, memoranda of agreement/understanding, or other legally binding documents;

- Engines used in the auxiliary power units must meet current emission standards must be certified by the ARB for sale in California, and must comply with applicable durability and warranty requirements;

- An hour-meter must be installed with the APU to record the actual operating time of the APU and to provide information on the number of hours the APU is utilized;

- The default load factor for the engine used in an auxiliary power unit will be the maximum power rating of the engine, unless other more appropriate load factors are proposed and supported by proper documentation;

- Funded projects must operate for a minimum of 5 years and emission benefits would be based on the vehicle's idling time that occurs in California;

- The actual installation cost of the APU including installation of an hour meter, or up to a maximum of $1,500 per diesel APU installation, and a maximum of $3,000 per alternative fuel, electric motor, or fuel cell APU installation may be funded, whichever is less; and

- Projects must meet a cost-effectiveness criterion of $13,000 per ton of NOx reduced.

C. Sample Application

In order to qualify for incentive funds, districts make applications available and solicit proposals for reduced-emission projects from heavy-duty vehicle operators. A sample application form is included in Appendix C. The applicant must provide at least the following information, as listed in Table X-2.

D. Emission Reduction and Cost Effectiveness

1. Emission Reduction Calculation.

The emission reduction benefit represents the difference in the emission level of a baseline idling emission level and the emission level of the auxiliary power unit. The emission level is calculated by multiplying an emission factor by an activity level, and, for the auxiliary power unit, by a load factor. Since emission standards for small off-road compression ignition engines are stated in terms of NOx plus HC, the total "NOx" emissions emitted from an engine used in an APU are determined using the applicable combined NOx+HC emission standards.

The NOx idling emission factors have been included in the recently adopted EMFAC2000 emissions model, which accounts for the settlement agreement between ARB and the diesel engine manufacturers (regarding excess NOx emissions from the use of alternative injection timing strategies). EMFAC2000 emission factors for truck idling are in units of g/hour. Idling NOx emission factors for heavy heavy-duty diesel trucks are shown in Table X-3.

2. Cost-Effectiveness Calculations

For auxiliary power unit projects, only the actual installation cost of an eligible new auxiliary power unit, will be funded through the Carl Moyer Program. The maximum installation cost, funded through the Carl Moyer Program, shall not exceed $1,500 for diesel powered APUs, and $3,000 for alternative fuel APUs. In order for a project to be considered eligible, the project must meet the $13,000 per ton cost-effectiveness criterion. The total installed cost of the auxiliary power unit is to be used in cost-effectiveness calculations. That amount is to be amortized over the expected project life (at least five years) and with a discount rate of five percent. The amortization formula (given below) yields a capital recovery factor, which, when multiplied by the initial capital cost, gives the annual cost of a project over its expected lifetime.

Table X-2
Minimum Application Information
Auxiliary Power Unit Projects

1. Air District 2. Project Funding Source: 3. Applicant Demographics Company Name: Business Type: Mailing Address: Location Address: Contact Number: 4. Project Description Project Name: Project Type: Vehicle Function: Vehicle Class: GVWR(lbs): 5. NOx Reduction Incremental Cost Effectiveness Analysis Basis: (Mileage/Fuel/Hours of Operation) 6. VIN or Serial Number: 7. Application: (Repower, Retrofit , Idling, or New) 8. Percent Operated in California: 9. APU Engine Information Horsepower Rating: Engine Make: Engine Model: Engine Year: Fuel Type:	10. NOx Emissions Reductions Baseline NOx Emissions Level (g/hr): APU NOx+HC Emissions Standard (g/kW-hr): Estimated Annual NOx Emissions Reductions: Estimated Lifetime NOx Emissions Reductions: 11. Cost ($) of Certified APU: 12. Installation cost ($) of APU: 13. Annual Diesel Gallons Used: 14. Annual Hours Idled (Must be documented or justified): 15. APU Load Factor (Must be documented or use default value): 16. Project Life (years): 17. Existing Truck Engine Information Truck Horsepower Rating: Truck Engine Make: Truck Engine Model: Truck Engine Year: 18. District Incentive Grant Amount Requested: 19. Project Contact:

Table X-3 NOx Idling Emission Factors for Heavy Heavy-Duty Diesel Trucks 33,000 + lbs GVWR	
Weight Class	**Grams per Hour**
Heavy Heavy-Duty Diesel Trucks	396

Capital Recovery Factor (CRF) = **$[(1 + i)^n (i)] / [(1 + i)^n - 1]$**

Where,

i = discount rate (5 percent)
n = project life (at least five years)

The discount rate of five percent reflects the opportunity cost of public funds for the Carl Moyer Program. This is the level of earning that could be reasonably expected by investing state funds in various financial instruments, such as U.S. Treasury securities. Cost-effectiveness is determined by dividing the annualized cost by the annual NOx emission reductions. An example calculation for heavy-duty truck idling reduction project through installation of an auxiliary power unit is provided below.

3. Example

Example 1 – APU Project (Calculations based on Fuel Consumption and Idling Hours). A truck operator proposes to purchase an auxiliary power unit, powered by a certified 8 kilowatt (10.7 horsepower) engine, to be installed on a heavy-duty truck to reduce its engine idling hours. This vehicle idles 100 hours per year in California. The load factor for the APU is documented to be 90% of rated power and the APU would substitute for up to 80% of the truck's idling time. The installation cost of the APU on the truck is $1,400.

Emission Reduction Calculation

Baseline Truck NOx Idling Emission Factor:	396 g/hr
APU NOx+HC Emission Standard:	10.5 g/kW-hr
Annual Idling Hours in California:	100 hours
Load Factor:	90%
APU Idling Substitution Rate:	80%
Convert grams to tons:	ton/907,200g

The estimated reductions are:

Since 80% of idling load is attributable to the APU, 20% of actual idling load is still carried out by the truck engine, the hourly NOx emission reduction is:

396 g/hr - ((0.20)(396 g/hr) + (0.80)(10.5 g/kW-hr)(8kW)(0.90)) = 256.3 g/hr

Annual emission reduction is:
256.3 g/hr* 100 hours/year * ton/907,200 g = **0.03 tons/year NOx emissions**

Cost and Cost-Effectiveness Calculations

The annualized cost is based on the installation cost of the auxiliary power unit, the expected life of the project (5 years), and the interest rate (5 percent) used to amortize the project cost over the project life. The maximum amount that could be funded through the Carl Moyer Program fund is determined as follows:

APU Capital Cost	= $6,000	
APU Installation Cost	= $1,400	
Moyer Amount Requested	= $1,400	
Capital Recovery	**=** $[(1 + 0.05)^5 (0.05)]/[(1 + 0.05)^5 – 1]$	= 0.23
Annualized Cost	= (0.23)($1,400)	= 322/yr
Cost-Effectiveness	= ($322/year)/(0.03 tons/year)	**= $10,733/ton**

The cost effectiveness for the example is less than $13,000 per ton of NOx reduced. This project would qualify for the maximum amount of grant funds requested, which, in this case, is the entire installation cost.

E. Reporting and Monitoring.

The district has the authority to conduct periodic checks or solicit operating records from the applicant that has received Carl Moyer funds for heavy-duty vehicle idling emission reduction projects. This is to ensure that the auxiliary power unit is operated as stated in the program application. Fleet operators participating in the Carl Moyer Program are required to keep appropriate records during the life of the funded project. Records must contain, at a minimum, total California hours idled. Records must be retained and updated throughout the project life and made available at the request of the district.